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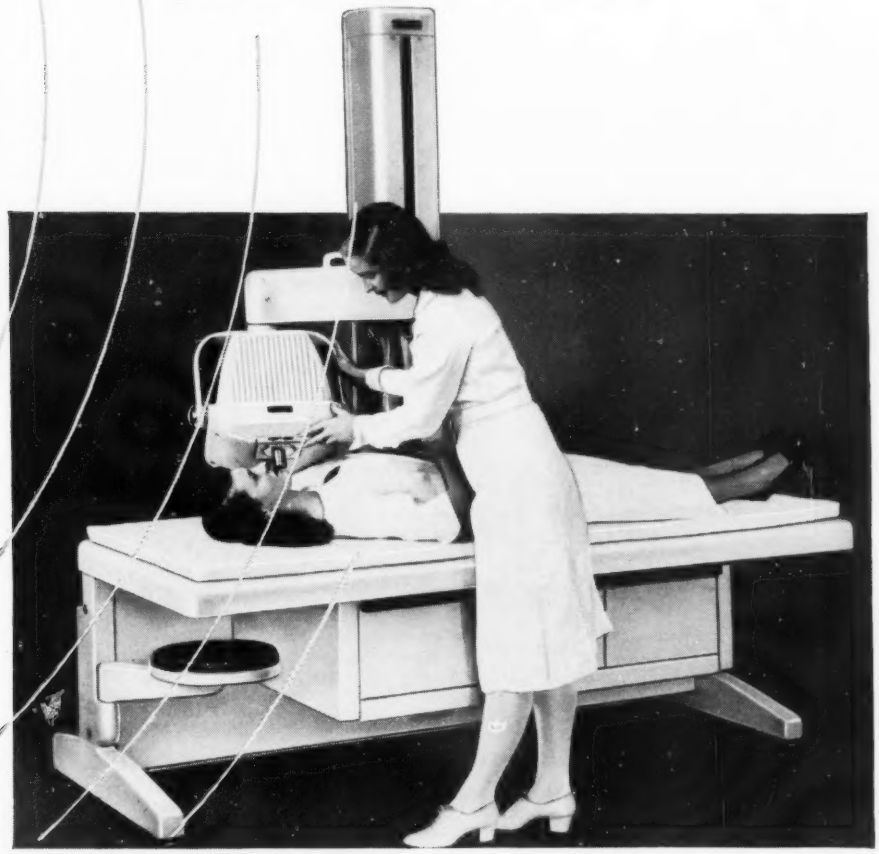

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EDITORIAL

Starting with the discovery of X-rays and radioactivity in the last years of the 19th century, there followed a series of brilliant experiments in nuclear physics leading to the discovery of uranium fission in 1938 and the subsequent building of nuclear reactors. The impact of these findings has been felt in many fields of medicine. War medicine has been complicated by the use of atomic bombs and by radiological warfare. The disposal of radioactive wastes from reactors has posed knotty problems in the field of public health. The growing use of radioactive isotopes in industry and research has intensified the already existing problem of protection of workers from ionizing radiations, a vexing one for industrial hygienists since information on this score is not abundant. There is the much publicized application to clinical diagnosis and therapy, and finally the important invasion of the field of medical research.

The application of radioactive isotopes to therapy takes two forms, the administration of such material internally and their use as substitutes for radium.

Treatment of cancer by internally-administered radioactive isotopes has been disappointing and this is not surprising since it rests upon selective absorption of the radioactive material by the cancer cells. Success of this method depends on further knowledge of the metabolism of cancer cells, a better understanding of the mechanism of action of radiation on living tissue, and studies of the metabolic behaviour of the substances used in therapy regardless of their radioactive properties.

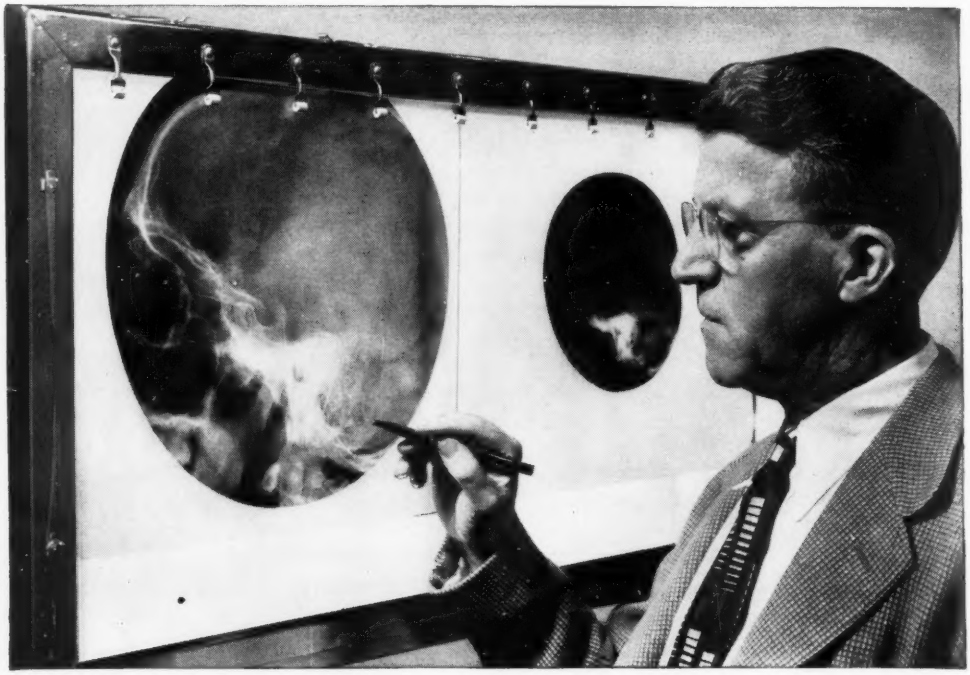
Of the existing radioactive substances, Cobalt^{60} seems to be the most suitable substitute for Radium. It has been used in interstitial, intercavitary, and beam therapy. Its advantages are that it can be produced in metallic form in any shape required, it does not evolve a radioactive gas, the initial distribution in needles or other applicators is stable, and it can be made in reactors in large quantities at reasonable cost. On the other hand, a system of dosimetry for its use is not as well developed as that for Radium, and its half-life is relatively short, 5.3 years, necessitating exposure correction during prolonged usage and periodic replacement of the source.

There is nothing special about Cobalt used in interstitial or intercavitary therapy, since the specific activities needed are not high. For beam therapy, a small powerful source is required to minimize self-absorption in the material of the source and to obtain a well-defined beam. The Cobalt for this application can only be produced in a high flux nuclear reactor if production time is a consideration. At the present, the Chalk River pile is the only source of such material. To date, three multicurie sources have been produced, each equivalent to about 1200 curies of Radium. These sources, being so powerful, not only supplant Radium beam therapy, but also compete with X-ray machines in the 2 to 3 million volt region. Housings have been designed for these sources to make them as convenient to use as a modern X-ray machine. Production of these sources is continuing at Chalk River, but at the present time is far exceeded by demand. The Cobalt beam therapy unit should enable cheaper and more widespread therapy for deep seated cancer.

With a high flux reactor, it might even be possible to make sources suitable for diagnostic radiology, and if such sources were small enough, better picture definition might result. Leading physicists are now working on the problem.

Though the application of artificial radioactive isotopes in medicine started in the early 30's, the vigorous propagation of the present program is only about 6 years old. Judging by the progress which has been made in the short time, we can reasonably expect a great deal more within the next decade.

A. J. CIPRIANI, M.D., C.M.



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PHYSICAL CHARACTERISTICS OF THE RADIATION IN COBALT^{60} BEAM THERAPY

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Professor of Physics, University of Saskatchewan and Physicist to the Saskatchewan Cancer Commission

Introduction

In August, 1951, 1100 curies of Co^{60} were loaded into a beam therapy unit in the University Hospital, Saskatoon. The unit was designed by the author and produced for the Saskatchewan Cancer Commission by the Acme Machine and Electric Co. in Saskatoon. The radioactive cobalt was produced in the Canadian atomic pile at Chalk River by the Isotope Production Branch. At the same time a source of equal strength was irradiated for the unit described in the previous paper. This paper includes a brief discussion of the Saskatoon unit and some of the measurements which have been carried out on it.

The Cobalt Source

The cobalt source consists of 25 discs of cobalt 0.5 mm. thick and one inch in diameter. These discs after activation were placed together to form a source one inch in diameter and ½" thick. The discs were loaded in the stainless steel cup shown in the insert of Fig. 1, by personnel of the Isotope Production Branch at Chalk River. A tapered cylinder of heavy metal, also shown in Fig. 1 was screwed into this cup, thus sealing the cobalt discs inside the closed container. In all subsequent operations the source unit shown in the insert of Fig. 1 was handled as one piece.

Cobalt has a high cross section for the capture of thermal neutrons so precautions were taken to insure that one layer of cobalt did not shield a lower layer during the irradiation. The 25 discs were spread out over the available space in the pile in such a way as to keep overlapping to a minimum. A discussion to appear elsewhere[1] shows that even with a disc 0.5 mm. thick the outer layers of the disc shield the inner layers from the incident neutrons. It is shown that the activity produced in a disc 0.5 mm. thick is only 78% of that which would be produced if there were no shielding. It is obvious that a source of cobalt one half inch thick cannot be irradiated satisfactorily as a unit.

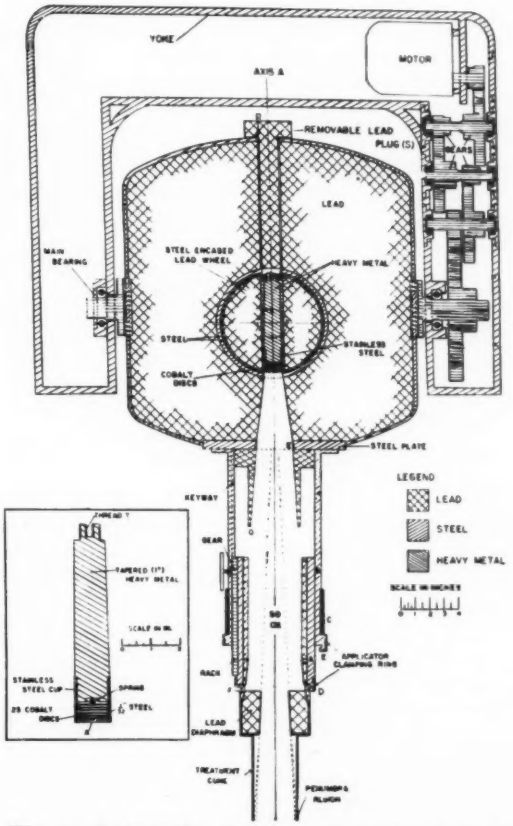

Fig. 1. Schematic diagram of treatment head, treatment cone attachments and the source unit.

Treatment Head

A diagram to scale of the treatment head is shown in Fig. 1. The unit consists essentially of a steel-encased lead-filled cylinder, with rounded ends, 20" in diameter, 22" high and weighing about 1 ton. This cylinder is arranged to rotate about a horizontal axis by the motor and gear chain shown. At the centre of this head is placed a steel-encased lead-filled

wheel which can rotate about an axis perpendicular to the plane of Fig. 1. One diameter of this wheel is made of a rectangular bar of heavy metal 1.5″ x 1.5″ x 7″. Along the diameter of this bar was drilled a tapered hole made to take the source unit exactly.

To load the unit the lead plug "S" was taken out and the treatment cone attachments which are fastened to the steel plate at the bottom of the head were removed. The shipping container was bolted to this steel plate. A clear hole thus existed along the axis "A" of the unit right down into the shipping container. A threaded rod was inserted from the top of the unit through the tapered hole in the wheel and then into the shipping container where it was screwed into the thread "T" of the source unit. Personnel was protected from radiation from the cobalt by the heavy metal tapered cylinder. The source unit was then pulled from the shipping container into the tapered hole in the wheel where it is secured. The lead plug "S" was then placed in position and the wheel rotated from the position shown in Fig. 1 through 180°. The cobalt is thereby surrounded by 10″ of lead in all directions except along the axis where it is shielded by 7″ of heavy metal. In the loading process care was taken to avoid contamination by cobalt dust. Details of this will be found elsewhere[1].

The unit may be turned on or off by a small two-phase motor connected to the wheel. The wheel is arranged on ball bearings and steel surfaces are supplied between all moving surfaces. Care was taken to arrange right-angle bends in all leakage paths to eliminate stray radiation emerging from the head through the cracks between the moving surfaces. A detailed discussion of the design of the wheel and treatment head will be found elsewhere[2].

Treatment Cones

The design of suitable treatment cones presents something of a problem for cobalt units since the lead diaphragms must be about 8 cm. thick. If continual adjustable diaphragms are used the size of the head becomes bulky. If replaceable lead diaphragms are used some difficulty is experienced in keeping the weight of these inserts small enough. We have chosen the latter method as is indicated in Fig. 1. For all field sizes up to a 10 x 12 cm. rectangular field the treatment cones with their attached lead diaphragms are mounted in the ring "D". When larger fields up to 20 x 10 are required the inner sleeve "A" is retracted by the rack and gear and the larger lead diaphragms with their attached treatment cones are mounted in ring "E". For the small fields the skin surface is 15 cm. from the limiting lead diaphragm. For the larger fields this distance is 20 cm. Due to the finite size of the cobalt source there is a penumbra region around each field. With a 15 cm. space between the limiting lead diaphragm and the end of the treatment cone the penumbra region shown in Fig. 1 is 6 mm. wide. The treatment cone is constructed of stainless steel and made large enough to avoid the edge of the penumbra region. Twenty different sized fields are available and no treatment cone attachment weighs more than 15 lbs. The ledge at D extends half way around the circumference of the cylinder A. A 20° sector of this ledge F is fastened to the applicator clamping ring which is threaded to the outside of the cylindrical sleeve. The diaphragm is placed in position by sliding the lip of the lead diaphragm into the ring. Once this is done the weight of the treatment cone is carried by the unit and the treatment cone may be clamped in position by rotating the section F through about 90°. Beam directing devices may be fastened to the stainless steel ring C which may be rotated and clamped in any position.

A pin and arc beam director attachment, the clamping rings for the treatment cones and other clinical devices are discussed in the paper by Dr. T. A. Watson.

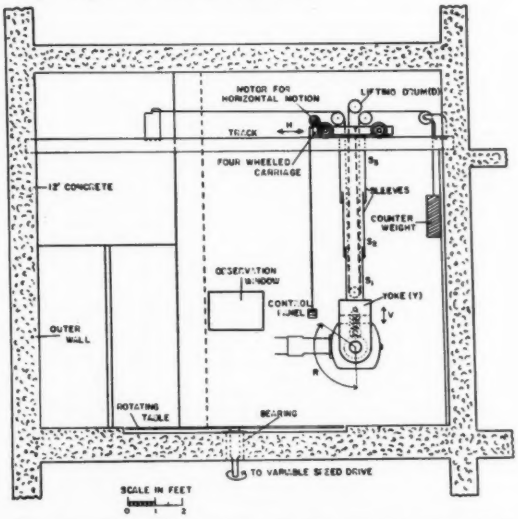

Fig. 2. Elevation view of the treatment room showing the unit and indicating the motions of which it is capable.

Treatment Room

The method of mounting the unit in the treatment room is shown schematically in Fig. 2. The unit is supported from an overhead carriage in such a way that the space below the unit is completely free. This is a big advantage in "porting" patients. The overhead carriage is moved along a horizontal track by a small motor geared to one of the wheels. Most of the weight of the unit is

carried by a counter weight. With the pulley arrangements shown in Fig. 2 motion of the carriage along the overhead track does not alter the vertical position of the unit. The unit is fastened to the carriage by telescoping steel sleeves and the unit may be raised or lowered by a motor mounted on the carriage. The unit is also capable of rotation about a horizontal axis. All of these motions are controlled through relays by a control panel shown in Fig. 2. In the floor of the room is mounted a steel table 8′ in diameter flush with the floor which will be used in rotation therapy. The vertical axis of rotation is marked by a light beam directed from the ceiling. The horizontal motion of the unit is essential for rotation therapy. In addition experience has shown that this motion is very convenient in "porting" a patient for ordinary therapy. The observation window is filled with 8 one inch layers of plate glass. The walls of the room are 12″ of concrete. The radiation is below tolerance at all points outside the room when the machine is turned on. When the machine is turned off the dosage rate 1 ft. from the head is less than 5 mr. per hour. Further details of protection measurements will be found elsewhere[2].

Interlocks are supplied on the doors of the treatment room so that if these doors are opened the cobalt is immediately returned to the off position. The unit cannot be turned on unless the doors to the room are closed. The control panel is very simple, consisting of a timer, a key-operated switch and two lights which indicate the position of the cobalt. Devices for rotation therapy are also mounted on the control panel. These consist of a meter which gives the time for one rotation of the steel turntable and a switch which controls this rate of rotation.

Radiations from Cobalt

The radiations from cobalt consist of two gamma-ray lines of energy 1.17 and 1.33 MeV. emitted in equal numbers, as the Co^{60} decays to Ni^{60}. A beta-ray of 0.3 MeV. energy accompanies this decay. Most of the betas emitted are absorbed in the source itself. Although the Saskatoon source has an actual strength of about 1100 curies its effective strength after corrections have been made for absorption and scattering of the radiation in the source itself is 950 curies. The unit gives an output of 33r per minute at 80 cm. The unit is used at 80 cm. source-to-skin distance. The cobalt decays at the rate of 1.1% per month and treatment times may be adjusted according to this figure.

In Fig. 3 the spectral distribution of cobalt radiation is compared with that produced by X-ray machines working at peak voltages of

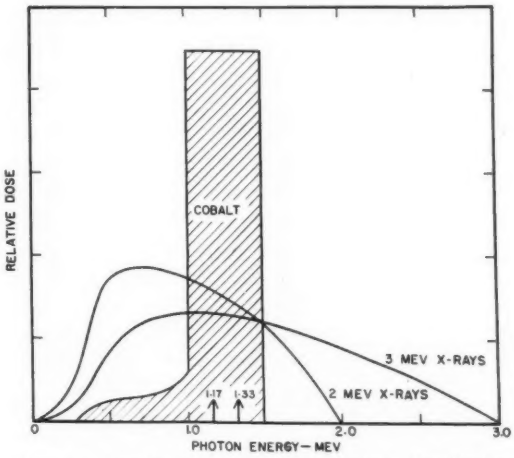

Fig. 3. Graphs showing the spectral distribution of radiation produced by X-ray machines operating with peak energies of 2 and 2 MeV. These are compared with cobalt radiation. The curves have been adjusted to include the same area and so all correspond to the same dose.

2 and 3 million volts. The spectral distributions from the X-ray machines were obtained by calculation from theoretical distributions for no filtration given by Heitler[7]. These distributions were modified by the absorption of 6 mm. of lead and 5 mm. of copper for 2 MeV radiation and 10 mm. of lead and 5 mm. of copper for 3 MeV radiation. These are the filtrations commonly used for 2 and 3 MeV X-rays[3]. In Fig. 3 the relative dose for each of the radiations in each energy interval is plotted against the energy of the photon. The curves have been adjusted to include the same area and thus correspond to the same dose. For cobalt the primary radiation consists of two lines at 1.17 and 1.33 MeV. These lines on Fig. 3 should be made very high and narrow, but for purposes of illustration the range of the cobalt radiation has been increased by equal amounts below 1.17 MeV and above 1.33 MeV. The height and width of the shaded area has been adjusted to contain the same area as the other distributions. The tail at the low energy end of the cobalt distribution is due to scattered radiation from the cobalt source[1]. It is seen that although the 2 MeV distribution contains harder components than the cobalt it also contains a large percentage of softer components. From inspection of Fig. 3 one might expect the depth dose from cobalt to be considerably better than from a 2 MeV X-ray machine and about the same as from a 3 MeV machine. Experiments to be described in the next section show this to be the case. It is interesting to note that the distributions for 2 and 3 MeV radiation cannot be improved very much through

further filtration because the absorption coefficient in lead is essentially constant from 1 to 3 MeV. Filtration therefore attenuates the more energetic radiation in about the same manner as the lower energy radiation. The radiations from cobalt cannot be improved by filtration.

Depth Dose data for circular fields at a variety of source-to-skin distances are reported elsewhere[1]. In Table I data for a number of rectangular fields are presented. The depth dose on the surface is hard to determine precisely and depends somewhat on the diaphragming system but the values given in Table I are approximately correct for the surface dose. These results are in good agreement with those obtained by Dixon et al[5] on the Eldorado unit discussed in their paper.

TABLE I

Depth Dose Data for Cobalt^{60}
Source-to-Skin distance 80 cm.
Field Sizes

Depth (cm.)	5x5	7x5	6x8	8x10	15x6	10x10	10x12
0	30	35	40	40	40	45	50
0.6	100.0	100.0	100.0	100.0	100.0	100.0	100.0
2	92.3	93.0	93.3	93.8	93.9	94.0	94.0
4	80.7	81.5	82.0	83.5	83.6	83.8	84.0
6	69.2	70.4	71.4	73.4	73.4	73.7	74.0
8	59.3	60.5	61.9	63.9	64.0	64.4	65.0
10	50.7	51.9	53.2	55.3	55.4	56.0	56.6
12	43.3	44.4	45.6	47.8	47.9	48.5	49.3
14	36.9	38.0	39.1	41.2	41.3	41.8	42.8
16	31.4	32.5	33.5	35.3	35.5	36.3	37.2
18	26.8	27.7	28.8	30.6	30.8	31.4	32.3
20	22.8	23.6	24.7	26.3	26.6	27.3	28.1

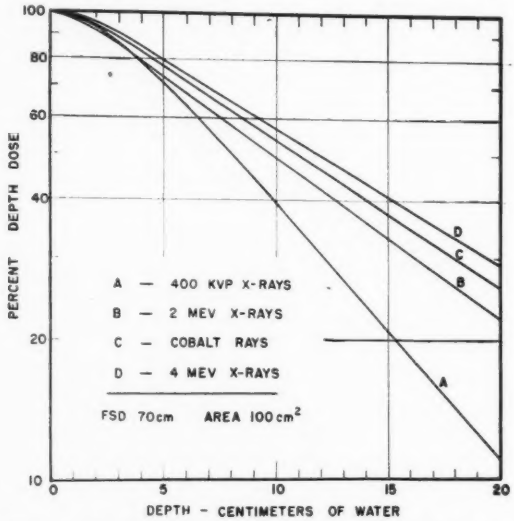

Fig. 4. Depth dose curves for four types of radiation. Curve A — 400 Kv, H.V.L. 4.0 mm. Cu.; Curve B — 2 MeV X-rays, filter 6 mm. Pb and 5 mm. Cu.; Curve C — cobalt gamma rays; Curve D — 3 MeV X-rays, filter 10 mm. Pb and 5 mm. Cu. All graphs are for 70 cm. F.S.D. and area 100 cm^2.

In Fig. 4 the depth dose for an area of 100 cm^2 and a focal skin distance of 70 cm. is given for a number of radiations. Curve A is obtained for 400 Kv, H.V.L. 4.0 mm. Cu. Curves B and D were obtained from Trump and Cloud[3] for radiations generated at peak voltages of 2 MeV (filter 6 mm. Pb + 5 mm. Cu.) and 4 MeV (filter 10 mm. Pb + 5 mm. Cu.) respectively. It is seen that the depth dose curve from the cobalt lies about midway between the 2 and 4 MeV curves. Actually it lies slightly higher than the 3 MeV curve published by Trump and Cloud. This is understandable from the previous discussion and the spectral distributions given in Fig. 3.

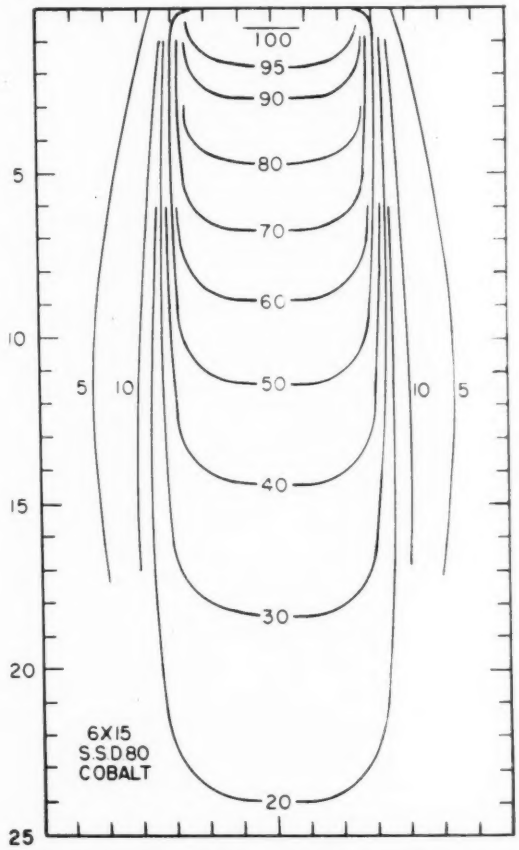

Fig. 5. Isodose distributions for 6 x 15 cm. field obtained from cobalt unit. Source to skin distance 80 cm.

Isodose Distributions

In Fig. 5 is shown the distribution of radiation for a 6 x 15 cm. rectangular field. Because of the penumbra produced by the large source there is no sharp discontinuity as the edge of the beam as is usually observed for 200 and

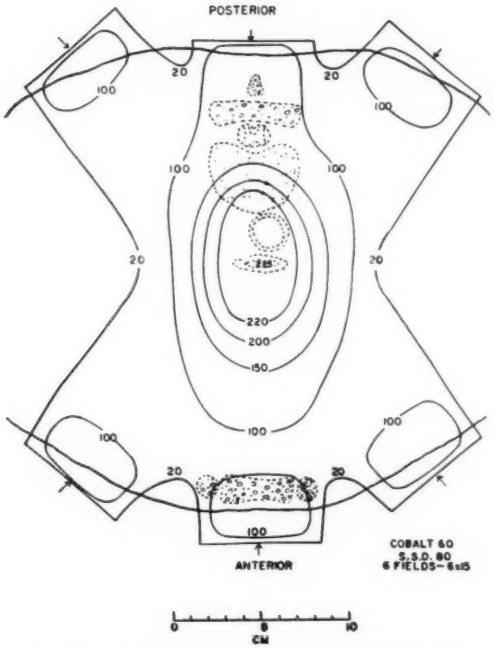

Fig. 6. Distribution obtained by combining 6, 6 x 15 cobalt fields in the treatment of cancer of the œsophagus.

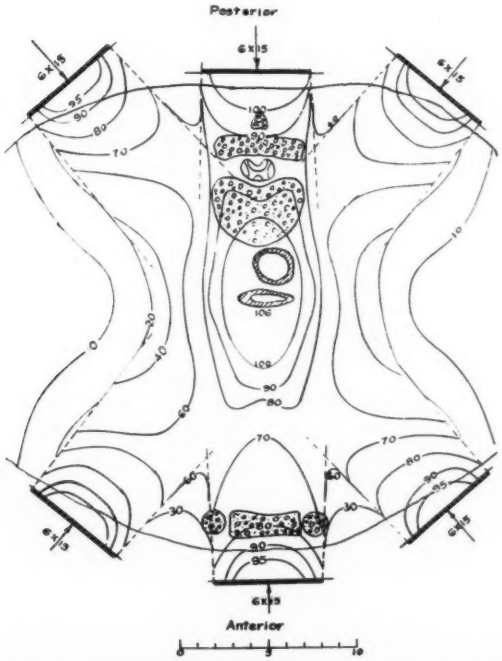

Fig. 7. Distribution obtained by combining 6, 6 x 15 400 Kv fields (H.V.L. 4.0 mm. Cu.) in the treatment of cancer of the œsophagus. This should be compared with Fig. 6.

400 Kv radiation[6]. In Fig. 6 six 6 x 15 distributions have been combined in the treatment of an oesophagus. For comparison a similar distribution obtained from the same sized fields using 400 Kv radiation is shown in Fig. 7. It is obvious that the cobalt presents a considerable advantage for this type of treatment where a tumor dose of 200% is obtained with cobalt as against 100 with 400 Kv radiation.

Conclusions

Co^{60} units give about the same depth dose as is obtained from a 3 MeV machine. They are much simpler to operate and should require little if any service. They suffer from the disadvantages of requiring a new source periodically. The present unit has an output 33r per minute at 80 cm. This is considerably smaller than that obtainable from 2, 3 and 4 MeV X-ray generators. However, sources of Co^{60} two to three times as strong as the present one could easily be made and handled. The cobalt unit is flexible in operation and can readily be arranged for accurate beam radiation.

Acknowledgments

The author is grateful to the National Research Council of Canada for making available this first experimental source of cobalt. Special thanks are due to Dr. A. J. Cipriani and to personnel of the Isotopes Production Branch at Chalk River. The assistance of S.O. Fedoruk, D.V . Cormack, E.R. Epp and L.M. Bates, graduate students at the University of Saskatchewan, is gratefully acknowledged.

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THE CLINICAL POSSIBILITIES OF THE COBALT^{60} BEAM UNIT

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The therapeutic value of supervoltage x-ray equipment up to 2 MeV is now well established and there is abundant literature showing that x-rays of this type can be employed advantageously as a routine in some kinds of malignant disease. The advantages offered by supervoltage x-rays over 200 - 400 Kv x-rays include a slighter skin effect, a greatly enhanced depth dose, particularly for small fields, a lesser integral dose for a certain dose to a given volume and less selective absorption by bone and cartilage. There is nothing revolutionary, therefore, in the use of large quantities of radioactive cobalt in beam units, since the rays produced are roughly equivalent to those generated by a 3 to 4 peak machine.

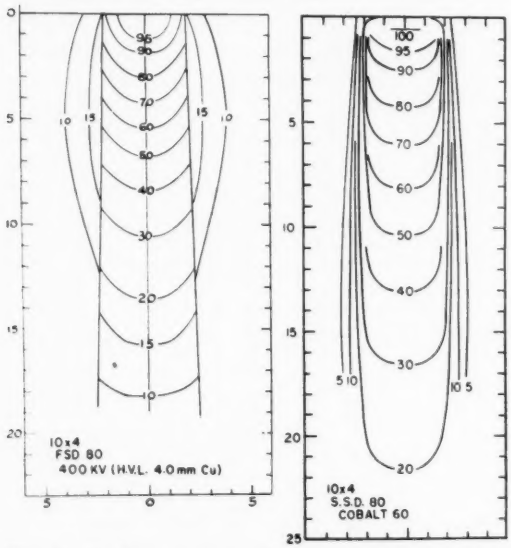

Fig. 1. Isodose curves of the same sized fields comparing 400 Kv with Cobalt^{60} Unit.

The Saskatchewan 1100 curie Cobalt^{60} unit has already been described. Compared with a 2 machine, this unit is considered to have the following advantages:

1. The initial cost is very much less.
2. The upkeep is expected to be low.
3. The unit is more compact and manœuvrable.
4. The output, subject to the steady decay, (1.1% per month), is constant.
5. The beam is much more homogeneous and no filtration is necessary.
6. A higher depth dose is obtained, (equivalent to 3.5 MeV).

The disadvantages of this unit are that the output (approximately 33r min at 80 cm. F.S.D.) is considerably less than that of a 2 MeV machine, and the cobalt, with a half life of 5.3 years, will probably have to be replaced in about three years. A further disadvantage is that the focal spot of 2.5 cms. in diameter produces a marked penumbra effect at the edge of the field. To reduce this penumbra to 6mm. at 80cm. F.S.D., the last lead diaphragm must be placed 15 cms. from the end of the cone.

Clinical Use

As we have been treating patients on this unit only since the beginning of November, 1951, all that can be described at this stage are the techniques employed.

In general it is considered that deep lesions suitable for small or medium-sized fields should be chosen and we are treating the type of cases which previously would have received 400 Kv therapy in our department.

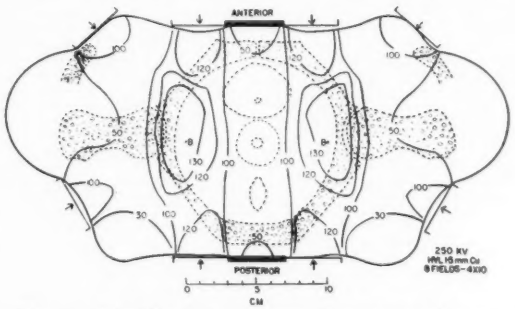

Fig. 2. Distribution of dosage in pelvis in the post-radium treatment of a case of cancer of the cervix using 250 Kv.

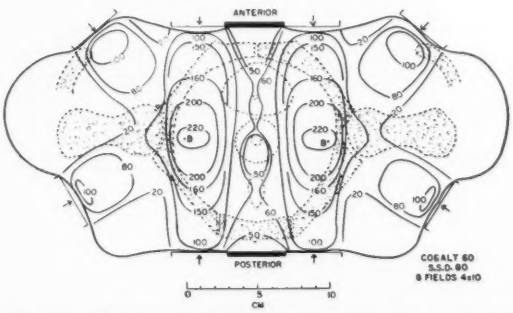

Fig. 3. Distribution of dosage in pelvis in the post-radium treatment of a case of carcinoma of the cervix using Cobalt^{60} unit.

This would include, for example, cancer of the œsophagus, larynx, pharynx, throat and possibly lung. It is also being used for irradiation of the parametria following radium treatment for cancer of the cervix, and in post-operative irradiation of the axilla and supraclavicular regions in cancer of the breast. Figures 2 and 3 demonstrate the different distributions of dosage obtained in the post-radium treatment of the pelvis for carcinoma of the cervix, using a 250 Kv machine in one instance and the cobalt unit in the other. It will be seen that the dose received at point B in the former is 130% compared to a maximum to the skin of about 125% — a ratio of approximately 1:1. In the case of the cobalt unit, this ratio is increased to 2.2:1. Wherever suitable, beam direction, using plaster casts and wax, is employed. A rotating section of the floor, eight feet in diameter, is for rotational therapy, either of the horizontal or vertical type.

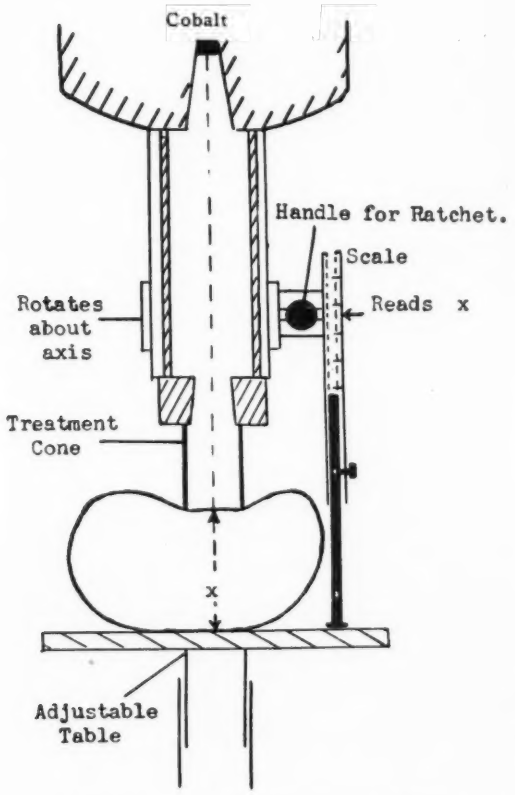

Fig. 4. Diagram of "compression rod".

We have chosen conventional cones, with open ends, rather than adjustable diaphragms since we believe that such cones ensure accurate positioning and focal skin distance, and permit compression. The open ends are not found to be unsuitable for this latter purpose. The ceiling suspension of the unit allows unrestricted movement on the floor. A compression rod, back pointer, and pin and arc can all be fitted, when desired, to a single fixture on the master-cone.

The unit has six mechanically operated movements controlled by push-buttons in a single small box, suspended from the ceiling, which is held in one hand. The buttons are arranged in three pairs — one pair for up and down movement, one for back and forth, and one for rotation of the head. The treatment couch is of the moving-top variety and can be pumped up or down. The table is usually used for the final adjustments.

Fig. 5. "Compression rod" in use.

In ordinary set-ups, where compression is desired, a simple attachment to the master cone allows one accurately to determine what compression is being used. The setting is noted and can be exactly reproduced daily (figs. 4 & 5).

For beam direction, using plaster casts and wax seatings, a back pointer is attached (fig. 6).

Fig. 6. Back pointer for beam direction.

For beam direction in sites where a plaster cast is unsuitable, a Manchester pin and arc attachment is fitted to the master-cone (figs. 7 & 8). A small spirit-level is attached to the pin so that it can easily be determined when the pin is vertical.

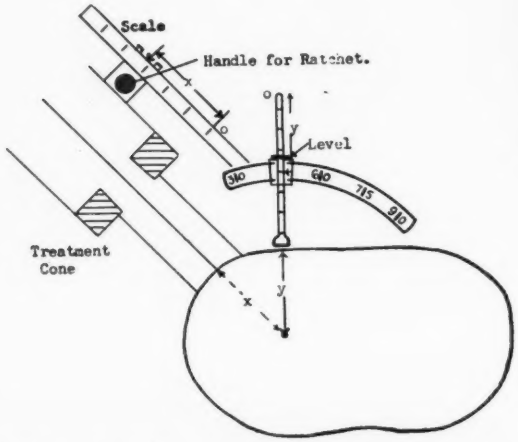

Fig. 7. Diagram of mechanism of "pin and arc".

We intend using rotational therapy in selected cases. We expect to use the horizontal type much more frequently than the vertical type, since with the former immobilization of the patient during the actual treatment is simple, whereas it is very difficult if the patient is sitting or standing up. Furthermore, with the vertical type, irradiation of cylindrical volumes (e.g. for cancer of the œsophagus) is the only possibility, unless complicating factors are introduced.

The setting up of a patient for horizontal rotation is quite simple. For example, let us imagine an inoperable lung tumor. The lesion is localized by x-ray films and the point overlying the centre of the lesion chosen on the anterior chest wall. Depending on the size and shape of the tumor, the best angle of incidence of the field, the size of the field and the radius of the point of entry from the point marked on the chest wall are determined from isodose curves obtained from various fields entering a water-phantom at different angles with no bolus materials in place. Once these factors are chosen direct measurements are made in a water container, whose surface is made to correspond with the contour of the chest wall by means of a plaster shell prepared from the chest of the patient. Accurate determinations of the desired tumor dose can now be made and the daily surface dose determined.

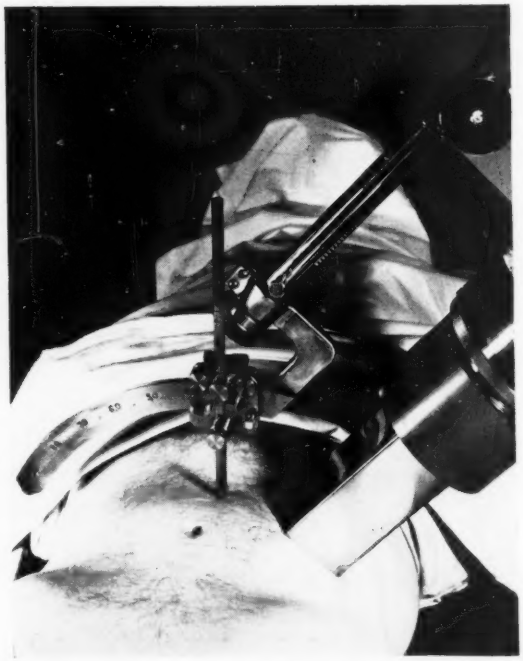

Fig. 8. "Pin and Arc", for beam direction, in use.

The patient lies supine on the treatment couch, which is wheeled on to the rotating platform. On the ceiling, immediately above the centre of the rotating platform. is a fixed light, which throws a tiny shadow in its centre. The treatment couch is now adjusted (fig. 9) so that the mark on the patient's chest is in the centre of the ceiling spot-light — i.e. the centre of the tumor is in the axis of rotation of the platform. The couch is braked in this position.

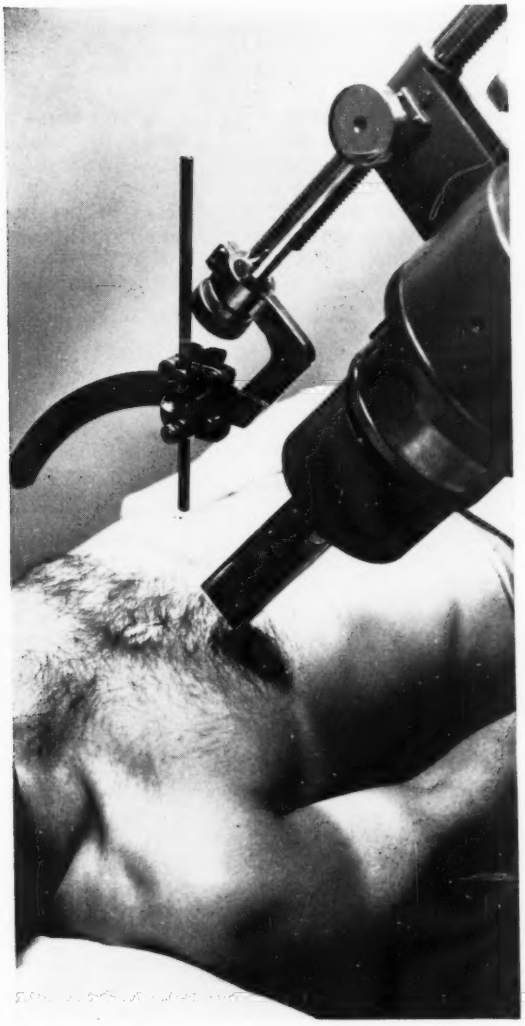

Fig. 9. Model set up for rotational therapy. Note the spot-light beam on the chest wall, its point coinciding with the cross on the skin. During actual rotation of the patient the tip of the light beam remains at the centre of the cross. Ratchet carrying pin and arc has been withdrawn after setting up the patient.

The unit, with the pin and arc attached, is now brought into place. It is rotated until, with the pin vertical, the desired incident angle is obtained. The pin is set back to the distance corresponding with the depth of the centre of the tumor from the anterior chest wall and its tip, by moving the head, is made to touch the point marked on the chest. The central ray of the beam is now traversing the centre of the tumor and will continue to do so, however much the patient is rotated. The focal skin distance used in ordinary treatment is 80 cms., but for rotational therapy 85 cms. will be used to allow of clearance of the skin by the ends of the applicator. Once the applicator is in the correct position, the pin and arc is withdrawn by the ratchet somewhat, so that again the ceiling spot-light strikes the point on the patient's chest. This spot can be watched during treatment to make sure the patient does not change his position. The daily exposure having been previously determined, the speed of rotation is now pre-set, so that the platform will revolve exactly twice during the exposure.

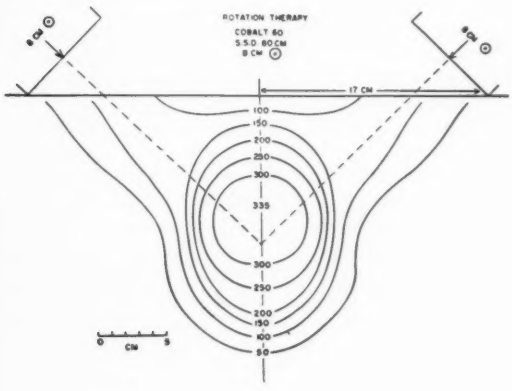

Fig. 10. Isodose curves obtained in a water phantom experimentally during rotation. The fields intersect 11 cms. below the skin margin. Note that the area of high dosage tends to be nearer the surface than at this point.

Figure 10 shows the distribution of dosage, using rotation therapy, for a flat surface. The beam is directed at 45 degrees to a point 11 cms. below the surface. These curves were obtained by Dr. Johns and Miss Fedorak using a water phantom and taking readings during rotation.

ROOM PROTECTION MEASUREMENTS FOR COBALT^{60} TELETHERAPY UNITS*

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The walls, floor and ceiling of a treatment room, in which a Co^{60} teletherapy unit is used, must be sufficiently thick to reduce the gamma-ray intensity outside the room to the tolerance level. While the main features of room protection problems are common to all beam therapy installations, it seems that the protection problem becomes more important as the conditions for teletherapy are better achieved. In order to deliver a dose to internal tumours which is high compared to the dose delivered to the intervening tissue, it is necessary to use a strong source at a distance from the patient, and to use penetrating radiation. A successful combination of these factors has the concomitant result that walls of a considerable thickness are required to protect personnel working in the area. Room protection for teletherapy units may then become a matter of some economic importance, and one which warrants a fairly detailed analysis.

The protection problem may be considered in two main aspects: protection against the direct beam, and protection against scattered radiation. Usually the beam direction is restricted to travel in a vertical plane, so that the major part of the protection design work is concerned with the scattered radiation. For a Co^{60} source the energy of this radiation is in the range 200 - 1200 Kv, depending on the angle of scatter.

The results of experimental measurements of the attenuation of the direct beam in concrete and lead, of the intensity of radiation scattered from a phantom and a wall, and of the attenuation of the scattered radiation in concrete and lead for various angles of scatter, are presented below. These measurements were made with a Co^{60} source with an output of 22 r/min at one meter. Full details of the experimental arrangements are available from the authors.

Protection Against Direct Beam

To specify the protection for the direct beam, one requires a knowledge of the gamma-ray intensity, the maximum beam size at the wall or floor in question, and the attenuation of the radiation in the protective material.

Intensity and Beam Size

The gamma-ray intensity is found to vary with distance approximately according to the inverse square law, so that it is sufficient, for protection purposes, to measure the output at one distance, say at two meters.

The beam size at any distance can be calculated as if there were a point source. However, there are several effects which cause a "smearing out" of the edges of the beam. These are: the extended source, radiating through a defining aperture, gives rise to a geometrical penumbra; the sides of the defining diaphragm scatter gamma radiation in all directions; and the diaphragm transmits a certain percentage of the incident radiation.

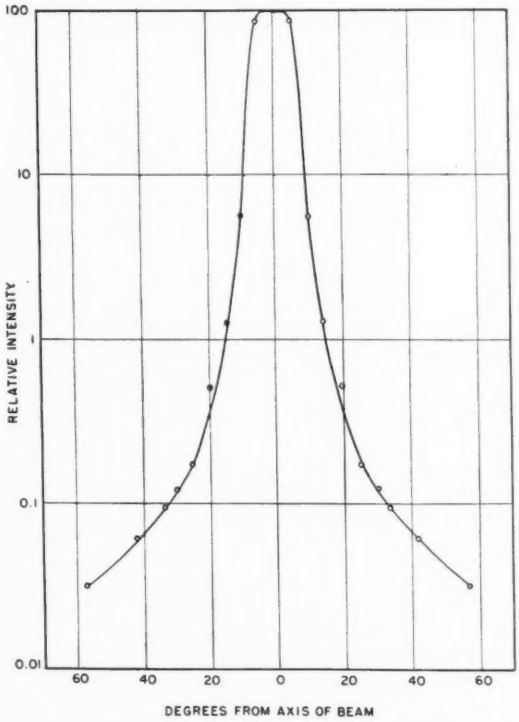

Fig. 1 Intensity profile of beam at 3 meters for a half-angle of 7½ degrees. Origin of co-ordinates at the source.

An example of the type of beam profile to be expected is shown in Fig. 1 as a plot on semi-logarithmic paper. The arrangement of

*This paper appeared in NUCLEONICS, Vol. 10, No. 3, March 1952, and is reproduced here with the permission of the editors of NUCLEONICS.

the defining diaphragm used for these measurements is shown in Fig. 2, with the phantom shown in Fig. 2 not in place.

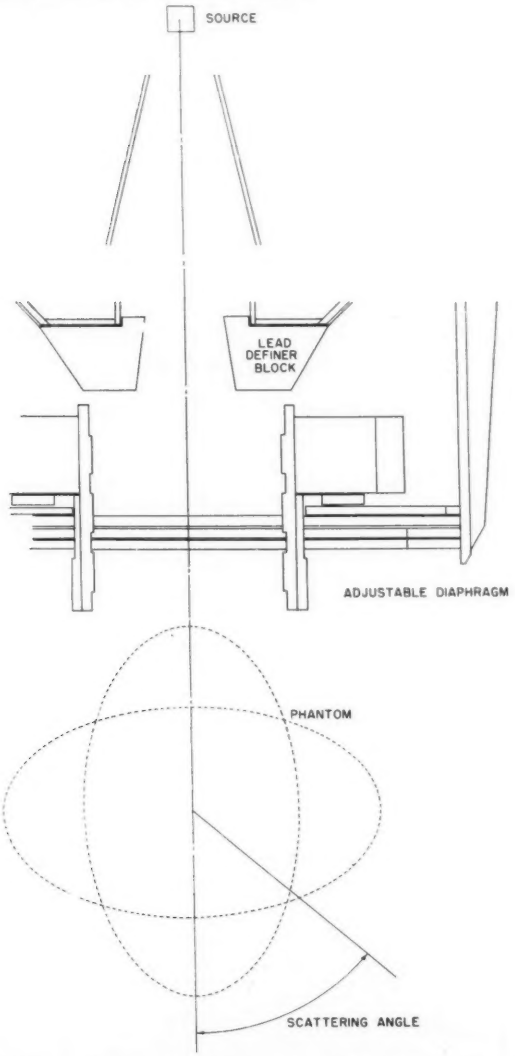

Fig. 2 Beam definition system used for the experimental measurements. (Printed with permission of Eldorado Mining & Refining (1944) Ltd., Ottawa.)

Absorption of Direct Beam in Concrete and in Lead

The attenuation of the direct beam through protective materials such as concrete and lead can be determined only by experimental measurements, since it is necessary to know the transmission in broad-beam conditions. The transmitted beam may be thought of as consisting of a direct component, and softer components which arise from scattering in the absorbing medium. These softer components become relatively more important as the absorber thickness is increased. For a given thickness their intensity increases with increasing field size, so that measurements should be made with the largest field to be used clinically.

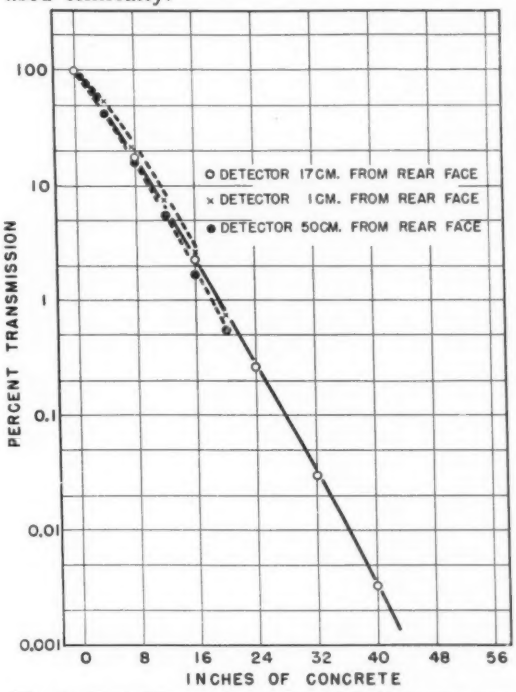

Fig. 3 Broad-beam absorption of Co^{60} gamma rays in concrete (density 2.37).

The results of our measurements are shown in Figures 3 and 4. The broad-beam transmission of Co^{60} gamma rays has been measured through 40 inches of concrete and through 22 centimeters of lead, with corresponding attenuations of 3×10^{-5} and 5×10^{-6} respectively. For these low values of the transmitted intensity it was necessary to shield the detector against the general room level of scattered radiation, but of course in such a way that gamma radiation scattered from a large area of the absorbing material was detected. A further complication is introduced if there is an appreciable percentage of back-scatter of the transmitted beam from shielding material behind the detector. Since the spectral distribution of the transmitted beam, and consequently the percentage back-scatter, depend on the absorber thickness, an appreciable error could be introduced. Measures were taken to minimize this effect.

For the concrete transmission a barrier 5′ x 5′ was used. The detector was located at a horizontal distance of 3 meters from the

source, and a fixed distance of 17 cm. from the rear face of the barrier. A circular field of diameter about 130 cm. at the detector was used. Without the barrier the measured intensity was 2.3 r min. A variety of air-wall ionization chambers were used as detectors, with the chamber wall thickness great enough to establish electronic equilibrium, and to exclude electrons ejected from the barrier.

The region behind the concrete barrier was shielded from general room scatter with large overlapping sheets of lead on frames 4′ x 8′. For a thickness of 48″ of concrete, the shielding was found to be insufficient, since the value of the transmission obtained was found to lie somewhat above the extrapolated curve of Fig. 3. The shielding did, however, reduce the measured intensity for 48″ by a factor of 13. The detector was located near an open window of dimensions 4′ x 4′, so that the effect of back-scattering was negligible.

Previous results which were obtained by the present authors with a much weaker source (0.8 r min at one meter) are shown as the dashed curves in Fig. 3. These curves show that the percentage transmission for the detector only a centimeter from the wall is higher, and that for the detector 50 cm. away, is smaller, than for the detector 17 cm. away.

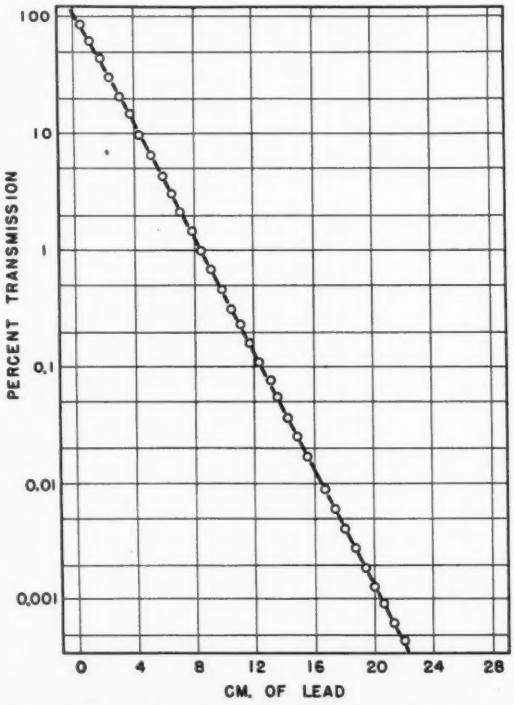

Fig. 4 Broad-beam absorption of Co^{60} gamma rays in lead.

Measurements of the broad-beam transmission of Co^{60} gamma rays through 24″ of concrete, made by Kennedy, Wyckoff and Snyder (1) are in good agreement with our results.

For lead transmission measurements the beam was directed vertically downwards. The detector was located at a distance of 75 cm. from the source, and about 9 cm. from the rear side of the lead absorber sheets, with a rectangular field 20 x 23 cm. at the detector. Lead shielding was provided on all sides. As well, lead was used under the detector since the intensity of the back-scatter from lead is appreciably less than that from materials of low atomic number. The results are shown in Fig. 4.

Protection Against Scattered Radiation

The side walls and ceiling must provide protection against scattered gamma radiation, which originates in the patient and in the parts of the walls or floor which are struck by the direct beam. It is convenient to consider that the scattered radiation in fact originates in virtual (anisotropic) sources, with their angular dependence being established by experimental measurements.

Intensity Distribution from Phantom

The intensity distribution of the gamma radiation scattered from a masonite phantom was measured, with the results shown in Fig. 5. The phantom was an elliptic cylinder with major axis 36 cm., and the minor axis 20 cm.

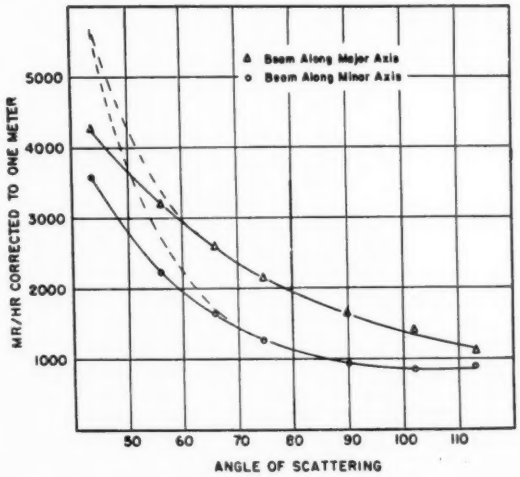

Fig. 5 Angular distribution of gamma radiation scattered from elliptic masonite phantom. The dashed curves are explained in the text. Source output 22 r/min, field size 26 x 26 cm, at one meter.

The scattered radiation has been measured with the beam directed along both the major and minor axes of the ellipse. A radiation survey meter, Beckman Model MX-2, was used. The beam was directed horizontally through an open window, at a distance of 3.5 meters, of dimensions 4′ x 4′. Lead sheets of thickness 1 16 inch were used to cover the area surrounding the open window.

The values plotted in Fig. 5 have been obtained from the measured intensities by multiplying by the square of the distance, in meters, from the phantom. The plotted values are averages of the results for distances of 1.5, 2, 2.5 and 3 meters.

The geometrical arrangement of the diaphragm and phantom is shown in Fig. 2, from which it is seen that in this case the beam is defined by the lead definer block. Gamma rays scattered from the block were absorbed to some extent in the material of the adjustable diaphragm. When the adjustable diaphragm (Fig 2) is entirely removed, and the phantom is left in the same position, one obtains results of the type shown by the dashed curves in Fig. 5. These curves show that for scattering angles less than about 60 degrees, the contribution from a defining diaphragm may be considerable, but that for scattering angles greater than 60 degrees, this contribution is small.

The output of the source used for these measurements was 22 r min at a meter, and the field size at a meter was 26 x 26 cm. Since the scattered intensity is proportional to the output, and to the area of the field at a given distance, the results shown in Fig. 5 may be easily converted to other source strengths and field sizes.

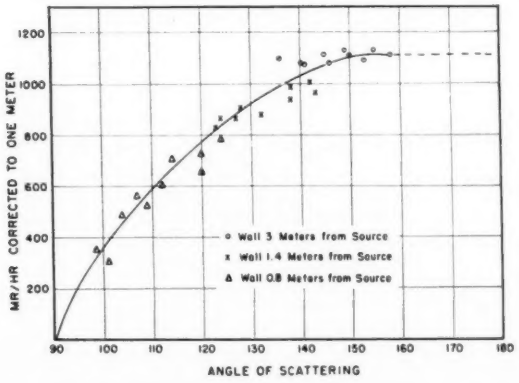

Fig. 6. Angular distribution of gamma radiation scattered from concrete wall normal to the beam. Source output 22 r min, field size 26 x 26 cm, at one meter.

Intensity Distribution from Concrete Wall

The intensity distribution of the gamma radiation scattered from a concrete wall, of thickness 8 inches, is shown in Fig. 6. The wall was placed normal to the beam at distances of 0.8, 1.4 and 3 meters from the source. The wall was placed at these various distances so that it would be possible to cover a wide range of scattering angles, and at the same time to be able to measure the intensity at points where the scattering from the defining diaphragm was small. The intensities of the scattered radiation have been measured at distances from the wall ranging from 1.5 to 4.5 meters, and the readings then converted by the inverse square law to a distance of 1 meter from the wall. The beam intensity and field size were the same as mentioned above.

Absorption of Scattered Radiation in Concrete and Lead

Experimental results for the absorption of the scattered radiation in concrete and lead, for various angles of scatter, are shown in Figures 7 and 8. The transmitted intensity

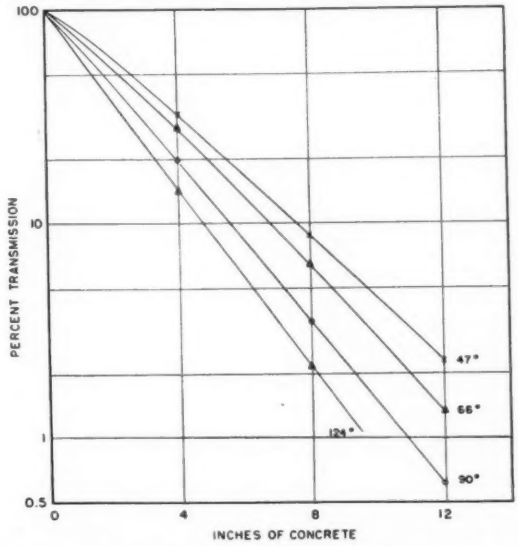

Fig. 7 Broad-beam absorption of scattered gamma radiation in concrete for various angles of scattering (density of concrete 2.37).

was measured with an ionization chamber and vibrating-reed electrometer. Shielding was provided around the detector against the general room level of scattered radiation, and with the shielding arrangement used, the part of the absorber which could scatter photons into the detector was 9 x 9 inches, at a distance of about 5 inches from the center of the ionization chamber.

The absorption curves for concrete show a concavity downwards which is typical of broad-beam measurements, while the absorption curves for lead, show a concavity upwards which is typical of measurements made with an X-ray beam consisting of a spectrum of energies up to a maximum value. The reason for this is that the absorption in lead is much more dependent on the photon energy than in concrete; a spectrum of energies arises from single scatterings through a small range of angles, and from multiple scattering.

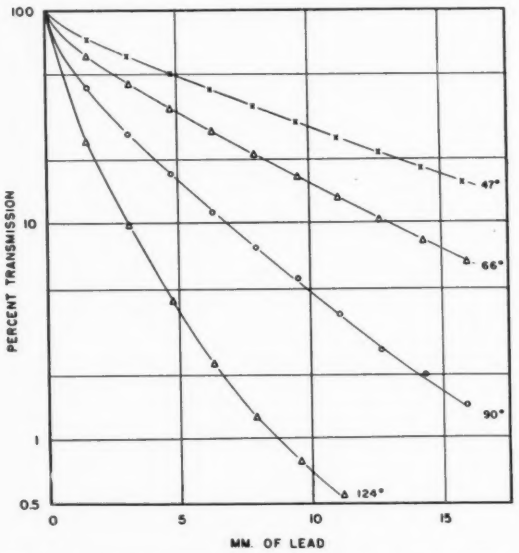

Fig. 8 Broad-beam absorption of scattered gamma radiation in lead for various angles of scattering.

Example Calculations

Consider a source with an output of 30 r min at a meter, located 3 meters from the front wall and 2 meters from the side wall of treatment room. In order to find the thickness required in the front wall, suppose that the intensity at a distance of 4 meters must be attenuated to a tolerance level of 6.25 mr hr, and hence by a factor of 18,000. The required thickness of concrete, from Fig. 3. is 38 inches, and of lead, from Fig. 4, is 17.5 cm.

The thickness required for the side walls should be calculated for a number of points. Consider for example a point 2.35 meters from the patient, and receiving radiation scattered through 90°. Assume the field size at one meter to be 26 x 26 cm. Then the intensity, from Fig. 5, is found to be 410 mr hr. To attenuate this to 6.25 mr hr (to 1.5%) requires 10 inches of concrete or 16 mm. of lead (Figs. 7 and 8). It is found that the thickness required in the more forward positions of the side wall is as much as 12" of concrete. For the backwall protection calculations one should assume scattering through an angle not larger than 90°, to take into account the most unfavorable scattering conditions (beam directed vertically downwards). For the example given the thickness required is of the order of 10" of concrete.

In most cases the intensity of back-scatter from the front wall or floor is much less than the intensity from the patient and in many cases may be neglected altogether, since the wall thickness required varies essentially as the logarithm of the intensity. If the back-scatter from the wall or floor must be considered, it may be assumed that the intensity of the direct beam is reduced to approximately 40% due to absorption in the patient. The contribution from the wall may then be added to the contribution from the patient, and the required protection thickness calculated as if the total intensity originated in the patient. Since the contribution from the wall or floor is, on the whole, of a lower energy than the contribution from the patient, this procedure may result in slightly overestimating the thickness required.

The authors wish to acknowledge the co-operation of Eldorado Mining & Refining (1944) Ltd., Ottawa, in this project.

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COBALT^{60} BEAM THERAPY: SOME INFLUENCES AND ADVANTAGES**

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The London Ontario Cobalt^{60} Beam Therapy Unit went into clinical operation October 27, 1951. Up to date, fifty-one cases have been treated. No one at this early stage would presume so much as to make clinical deductions, yet it is timely that we reveal our impressions of the influence of this powerful new radiotherapeutic weapon upon certain aspects of cancer control and management.

The Psychological Influence of Cobalt^{60} Beam Therapy affects the Public, the Patient, the Physician, the Physicist and the Canadian Cancer Society. By the *Public*, the announcement of Cobalt Teletherapy is hailed with satisfaction, revealing, as it does, that atomic energy in massive proportions is being constructively used to conserve public health rather than to destroy it. Furthermore, there is a quickened reassurance that scientists, in this instance the physicist and engineer, are persisting and progressing in their specific efforts to more completely combat cancer. For the *Patient*, hope is increased, morale is boosted, and rightly so within reason. On the *Physician*, dealing year after year with perplexing deep-seated cancer, the impact of Cobalt^{60} is astounding. Placed in his hands is a tangible culmination of scientific research and radiotherapeutic aspirations since 1896. He too, realizing the potential possibilities to be gained from improved physical qualities of the beam, experiences a deep-seated boost in morale which in turn is reflected to his colleagues. The Radiation *Physicist*, ever willing and able to cope with the challenge of scientific dosimetry, now has added to his armamentarium another powerful source of ionizing radiations. His field of endeavour becomes increasingly attractive, his basic research expanded, his collaboration indispensible. Meanwhile, the *Canadian Cancer Society*, heartened by progress, realizes the ever increasing importance of intensifying its educational program in early diagnosis.

THE INFLUENCE OF COBALT^{60} BEAM THERAPY ON RADIOTHERAPY PRACTICE:

Initial impressions of how Cobalt^{60} Teletherapy or its equivalent in super-voltage will affect the practice of therapeutic radiology as applied to cancer include:

1. Will not replace conventional equipment; e.g. X-Ray, Radium, Radon or Isotopes.
2. Will expand the effectiveness of Radiotherapy.
3. Demands Radiation Physicist.
4. Places added emphasis on centralization of Radiotherapy.
5. Will place us closer to "State Medicine".
6. Cobalt^{60}, or its equivalent, will be a "must" for any Department handling 500 new Therapy cases per year.
7. Permits utilization of rotation therapy to its fullest advantage.

Each item is fairly self-explanatory. One might generalize by saying we have passed the pioneer stage of radiotherapy, and have entered the era of refinement, of precision technique and exact dosimetry, none of which can be obtained without skilled professional and technical manpower, wide variation in equipment and ample clinical material. These essentials, coupled with the cost of housing and maintenance, place today's radiation therapy department beyond the means of the average individual or hospital, and point the way toward centralization and subsidy.

THE INFLUENCE OF COBALT^{60} BEAM THERAPY ON RADIOTHERAPY TECHNIQUES:

For effective illustration of cardinal points involved, three different tumours have been selected. In each, beam direction isodose studies have been carried out for 250 Kv constant potential X-radiation of a half value of 3.7 mm copper at an F.S.D. of 50 cm, as compared with the radiation from the 1300 curie-equivalent Cobalt^{60} beam therapy unit having a half value layer of 14.9mm copper at an F.S.D. of 100 cm. Depth dose readings at 10 cm for the 250 Kv unit were 32% as compared with 56% for Cobalt^{60} using 6 x 8 fields.[1] Comparative output was 62 r per minute at 250 Kv versus 20 r per minute from the Cobalt^{60} plant.

Presented at the Annual Meeting of the Canadian Association of Radiologists, Winnipeg, Manitoba, January 18, 1952.

(a) A fourteen year old male presented a recurrent angioendothelioma completely filling the right nasopharynx, occluding the ipsilateral nasal passage and measuring irregularly 3 cm in diameter. Regarded pathologically as benign, yet recurring after repeated surgery, irradiation was elected to manage the case. The tumour being ill-defined peripherally, interstitial irradiation would be most empirical at the best, hence external therapy was decided upon to produce a tumour dose of 2000 r in seven days; to be repeated in two months if necessary.

RIGHT POSTERIOR NASAL CAVITY
(ANGIO-ENDOTHELIOMA) TREATMENT WITH 250 KV X-RAYS
USING 4x4 cm FIELDS

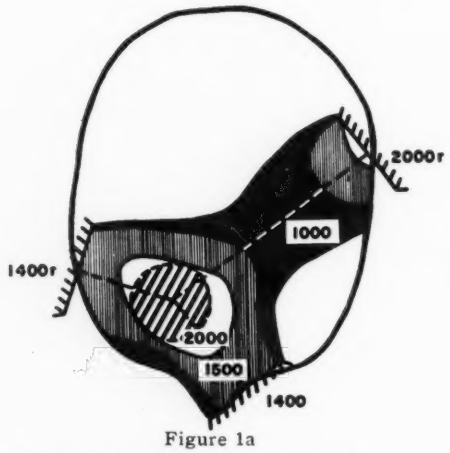

Figure 1a

RIGHT POSTERIOR NASAL CAVITY
(ANGIO-ENDOTHELIOMA) TREATMENT WITH Co60 BEAM UNIT
USING 4 x 4 cm FIELDS

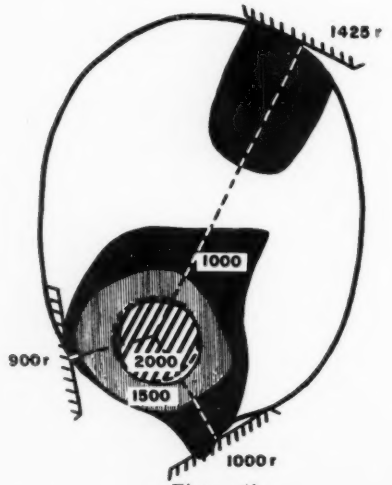

Figure 1b

A three field technique, using plaster shell, back pointer and 4 x 4 cm portals appeared optimum. With Co^{60} (Fig. 1A) the well-defined tumour dose area is labelled 2000 (heavy oblique lines coincide with tumour area): the adjacent 1500 r area (light vertical lines) is well-defined and localized about the tumour in contrast to the same dosage range at 250 Kv (Fig. 1B), which is more widely spread out, and even appears beneath the skin. Perhaps the most striking difference, in view of the likely requirement of a second similar course of treatment and the importance of inducing no irreparable damage to the integument of face and scalp, is the low skin dose required with Co^{60} to achieve the prescribed 2000 r tumour dose.

Of paramount consideration also, where developing facial bony structures are in association with tumour, is the low absorption co-efficient of bone for the 2.5 MeV range. Until specifically proven for radioactive cobalt, it seems reasonable to accept a co-efficient of absorption of o.12 in contrast to o.23 for 250 Kv X-ray.[2]

These observations do not preclude the possibility of treating this tumour by conventional means with an increased number of fields, treatment distance and filtration, but are presented as an illustration of how Co^{60} beam therapy can be used with comparative ease and ultimate safety in the management of this tricky lesion.

Indeed, after only two and one-half months of operation, no deep-seated tumour passes through our hands without thoroughly investigating the advantages to the patient that might be realized from substituting "Cobalt".

(b) The diagrams shown in Figures 2A and 2B are compiled from isodose studies on a case of carcinoma of the rectum, technically inoperable because of extent. 5000 r tumour dose was prescribed, to be delivered in three weeks. Using small portals, beam directed by pin and arc, a five field technique is very acceptable and, missing the bladder as it does, is perhaps most desirable. The upper part of each diagram represents the posterior surface.

A close survey reveals the 5000 r tumour dose (oblique heavy lines coincide with tumour) may be achieved readily by either apparatus. Similarly the 4000 r adjacent tissue spread (light vertical lines) is fairly comparable, but the appreciable difference in the volume of tissue receiving the 3000 r dosage (solid black) from 250 Kv X-rays

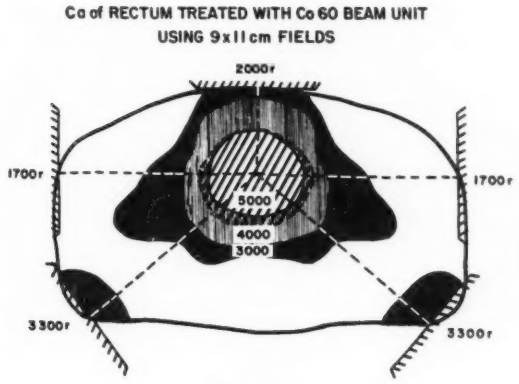

Figure 2a

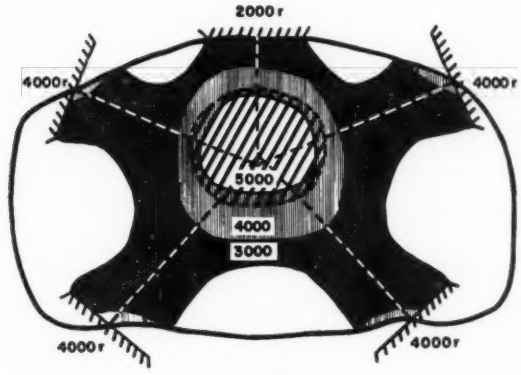

Figure 2b

(Fig. 2B) as compared with Co^{60} (Fig. 2A) is most obvious. This solid black 3000 r range is visible evidence of the higher volume tissue dose received from conventional therapy and may well be responsible for increased diarrhoea and greater systemic clinical reactions than obtained from Co^{60} Teletherapy, (which even with our short observation period appear to be less.) Such physical and clinical evidence is in accord with super voltage of similar MeV potential.[3, 4]

It is to be noted the highest skin dose obtained from the Co^{60} plan is 3300 r which in three weeks will produce a faint erythema, while that from the 250 Kv X-ray is 4000 r, a dosage of moist desquamation. Even with the small 6x10 cm X-ray fields our experience is such that for safety the prescription as outlined would have to be extended over four weeks: whereas with the Co^{60}, 5000 r tumour dosage in three weeks is tolerated.

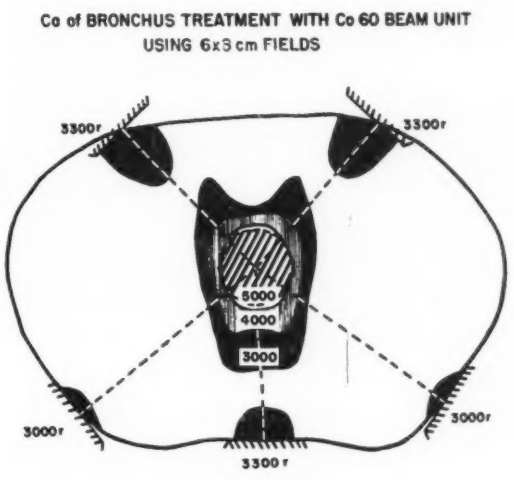

Figure 3a

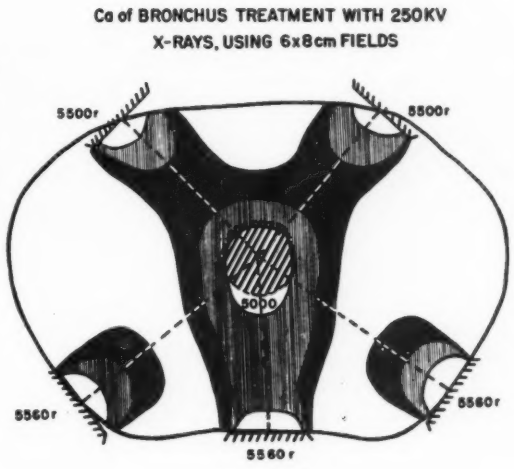

Figure 3b

(c) The dosage studies (reproduced in Figures 3A and 3B) for an early bronchogenic carcinoma technically inoperable because of its carinal position, were made to deliver a 5000 r tumour dose over a 5 cm area. Considering skin dose, this was possible over three weeks with Co^{60} Teletherapy but five weeks would be required for a similar plan with 250 Kv X-ray.

For comparative purposes the specific tissue differential absorption effects were ignored, the interspersed tissue media being conceded of unit density for practical purposes. A five field optimum was accepted using plaster jacket, with back pointer for beam direction (Figure 4).

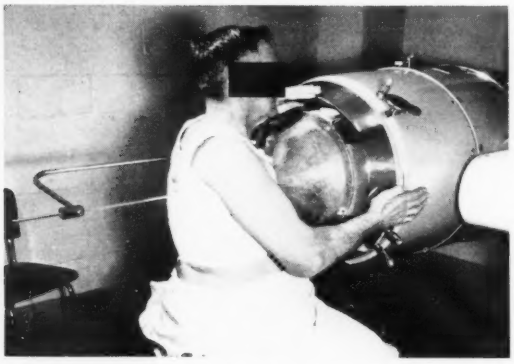

Fig. 4. The Cobalt 60 Unit positioned for treating bronchogenic carcinoma, multiple(five) portal technique using plaster jacket and back pointer.

Although the maximum depth dose with our Cobalt^{60} unit is 6mm beneath the surface, we for the time being, are assuming the plaster thickness may well bring this "hot" point into the dermis.

Observations on this point are but a few of the many to be made on this new therapeutic weapon.

A careful scrutiny of the dosage levels indicated numerically and by shading, confirms in principle the advantages as detailed in the previous nasopharyngeal and rectal cases, to be gained by substituting Cobalt^{60} Teletherapy for conventional X-ray. To support the physical visible evidence of a low volume dose we can report the constitutional side effects on three cases of bronchogenic carcinoma so treated to be relatively nil; and the patients haematologically unaffected.

(d) An artist's representation of dosage concentration based on isodose field studies (Figures 5A and 5B), using shading intensities to parallel irradiation intensities, illustrates rather graphically the difference in low skin and subcutaneous dosage delivered by Cobalt^{60} versus 250 Kv X-rays to obtain the same central dosage using a four portal, through and through technique.

SUMMARY: Comments are recorded on certain influences and advantages of Cobalt^{60} Teletherapy, based on initial impressions and observations of the unit in London, Ontario.

I am indebted to Dr. Frank Batley and Mr. Jack Brown for assistance with the isodose studies.

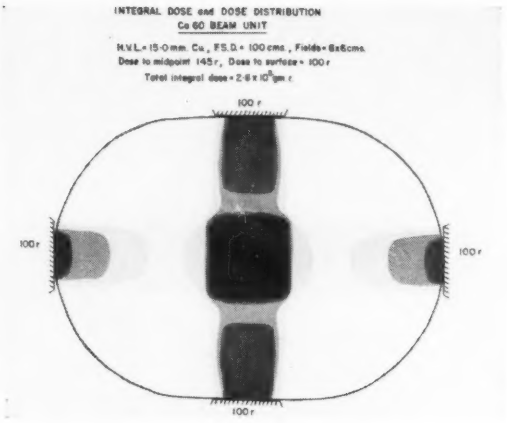
INTEGRAL DOSE and DOSE DISTRIBUTION
Co 60 BEAM UNIT
H.V.L. = 15·0 mm. Cu., F.S.D. = 100 cms., Fields = 6x6 cms.
Dose to midpoint 145 r, Dose to surface = 100 r
Total integral dose = 2·6 x 10⁵ gm. r
100 r
100 r
100 r
100 r

Figure 5a

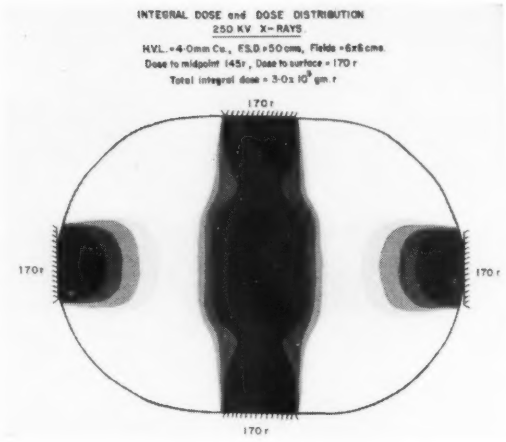
INTEGRAL DOSE and DOSE DISTRIBUTION
250 KV X-RAYS
H.V.L. = 4·0 mm Cu., F.S.D. = 50 cms., Fields = 6x6 cms.
Dose to midpoint 145 r, Dose to surface = 170 r
Total integral dose = 3·0 x 10⁵ gm. r
170 r
170 r
170 r
170 r

Figure 5b

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(1) Morrison, A. National Research Council of Canada: Personal Communication.

(2) Spiers, F. W. Effective atomic number and energy absorption in tissues. Brit. J. Rad, 1946, 19, 52-63.

(3) Phillips, Ralph. Super-voltage X-ray therapy 1944.

(4) Trump, John G. Moster, Clarence R. and Cloud, Robert W. "Efficient Deep Tumor Irradiation With Roentgen Rays of Several Million Volts".

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CONSIDERATIONS IN THE DESIGN OF A COBALT^{60} BEAM THERAPY EQUIPMENT

by
D. T. GREEN*, B.Sc., and R. F. ERRINGTON*, M.A.

Introduction

The availability of pile-produced gamma-ray sources of high output, small physical dimensions and high energy has led us to design an equipment for their use in super-voltage therapy. Since the utility of such sources and in particular Co^{60} must be largely assessed on economic grounds, it has been necessary to consider economic as well as technical problems in arriving at a final design. Source handling, shipping and loading, a suitable treatment head, incorporating a shutter system, beam definition, beam direction and a structure providing manoeuverability and support for the treatment head, are described in this paper. Co^{60} sources of several thousand curies activity may be used in this equipment.

Source Handling and Loading

The source available for the first Unit was made up of a number of thin Cobalt discs of diameter 1 inch which, when stacked, produced a right cylinder about ¾ inches high. The Unit has been designed to use sources with a maximum diameter of 3.3 cm. and a maximum roentgen output of 60 r/min. at 1 meter when installed.

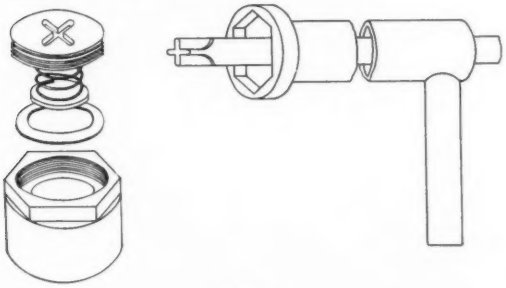

Figure 1

The source capsule is shown in Figure 1. This can be opened or closed readily while in the drawer in the transfer case by means of the tool shown, operating through the 6" diameter hole. The lead gasket provides a dust-tight seal for the source.

A method is required for loading sources into the head after the unit is installed in a hospital, and for exchanging full-strength sources for decayed sources. To fulfil these functions a "shipping and transfer" case was built which provides the protection and features required.

The transfer case is a lead shield, completely encased in steel, approximately spherical in shape, as shown in Figure 2. A removable

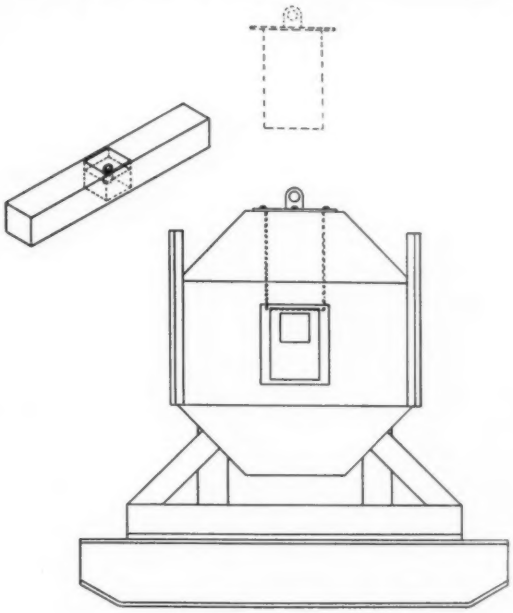

Figure 2

plug, 6" in diameter, gives access from the top of the case to the centre section of either of two horizontal lead drawers, which lie one above the other along a diameter of the case. These drawers slide freely in steel-lined square holes 3" x 3" in cross-section, and have an open section in the centre 3" long and 2¾" wide. With the plug removed, access is provided through this hole to the centre section of either drawer.

The problem of loading sources into the head on a routine basis, after the equipment has been installed, was also considered, as well as the method of exchanging decayed sources for new ones. The head has a steel drawer housing, 3" square, extending from front to back. This is accessible from either end by removing stepped lead blocks which trap scattered radiation. This housing will take one of the standard lead drawers which fit the shipping and transfer case. To load a

*Commercial products Division, Eldorado Mining and Refining (1944) Ltd.

source into the head, the transfer case is placed with its drawer-hole aligned, and in contact with, the drawer hole in the head, and the drawer, containing the source, is merely pushed through from one to the other. The actual movement of the drawer takes one or two minutes to perform, and dosages of 15 mr. are typical for operating personnel. This low level of exposure is possible because the two operators would be stationed one at the outer end of the drawer hole in the head and the other at the outer end of the drawer hole in the transfer case. In these positions, the radiation field is very low, even when the source is just passing from the case to the head. The radiation field at that moment is quite high however, in a plane through the contact surface of the two shields. But by building a temporary shielding of lead blocks around the point of contact of the lead and shipping case, stray radiation to other parts of the building during this short time can be readily kept to a very low value (less than 50 mr.) Since two-drawer holes are provided in the transfer case, one above the other, and since the case is so built that a source in either drawer is adequately protected, it is a simple matter to exchange sources between the transfer case and the head in two or three hours. Most of this time, of course, is consumed in aligning the drawer holes opposite each other in the two heavy shields.

Treatment Head

A choice had to be made between lead, tungsten alloy, or a combination of the two, as primary protective materials for the source. Although the size and weight of the housing could be reduced by the use of tungsten alloy instead of lead, this could only be done at a considerable added expense for raw materials and fabrication. It was decided that any advantages gained in this way were not sufficient in normal therapeutic use to warrant the added expenditure, and therefore lead was used for all the fixed protection. Unalloyed lead is not a very good structural material, however, since it tends to flow or creep slowly at room temperature and, if under any appreciable load, this cold flow is sufficient to cause dimensional changes which would seriously interfere with any precision mechanism. Rather than reduce the absorption coefficient of the lead by adding alloying metals, it was decided to cast the lead into a steel case which would provide all the necessary structural strength and be used for all finished surfaces. It should be also noted that, if the lead shield is not totally enclosed in steel, a fire in the hospital might result in an exposed source should the lead be raised to its melting point.

In calculating the lead thickness required, a source to deliver 33 r/min. at 1 meter in air was assumed. All protection was calculated to reduce the field at all exposed surfaces of the housing to less than 6.25 mr/hr. In addition, a design safety factor of 4 (2 half value layers) was added. Using a linear absorption coefficient of 0.60 cm.$^{-1}$ for broad beam Co^{60} gamma radiation in lead, we used a final lead thickness of 28.0 cm. or 11" as a minimum for protection in the equipment head.

Measurements showed that the dosage at the surface was somewhat higher than anticipated, but was still well below 6.25 mr/hr. over the greater part of the shield surface, so that a source delivering 60 r/min. at 1 meter could be accommodated.

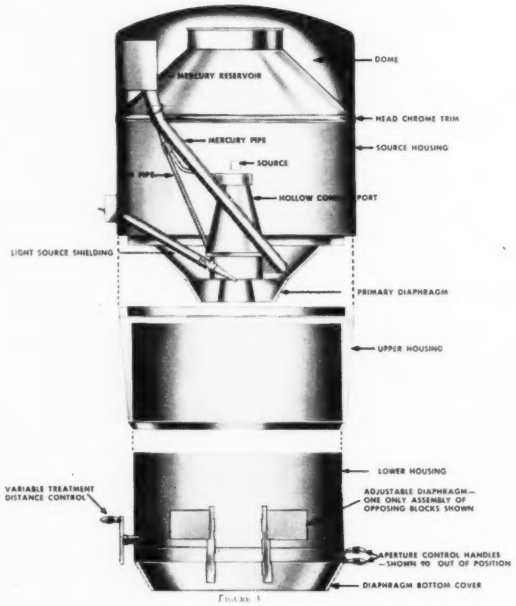

Figure 3

Considerable attention was given to a shutter mechanism for turning the beam "on" and "off" (fig. 3.). Such a system may involve moving the source within the shield, or moving shielding material in and out of a "port" or aperture. To use the minimum possible weight of shielding material compatible with complete protection, the shield should be spherical with the source located at the centre. A shutter mechanism which requires movement of the source from this central position would then require something more than this minimum shielding. To design a shutter mechanism of this type, which allows the source to be readily removed in the event of failure of the mechanism, does not appear

easy. For these reasons, it appeared preferable to design a shutter mechanism independent of the source and the loading method, so that in any event the source could safely be removed.

In the design finally evolved, the source is contained in a lead drawer which slides through a diametrical hole in the shield. By sliding this drawer partially through the shield, so that the source is midway between the centre and the outside surface, the radiation level in the room can be reduced to a level which allows work to be done on the equipment in the event of failure of the shutter mechanism. Otherwise, the source remains fixed in the centre of its approximately spherical shield, while shielding material, in the form of a truncated cone, extending radially from the end of the source to the outer surface of the shield, is moved in and out of this "port" to turn the beam "off" and "on". The use of a fluid shielding material moved by compressed air offers several advantages, mercury being the obvious choice for the fluid. By building stainless steel air lines, port, and mercury outlet lines into the steel shell of the head, then casting the lead around these parts, a simple, rugged and compact structure was achieved. No moving parts except mercury are within the lead shielding. By positioning the mercury reservoir, so that it is always at a higher elevation than the port, gravity is available as a closing force. The top and bottom of the stainless steel, conical chamber forming the exit port for the beam can be made quite thin (approximately 1 mm.) since pressures no greater than 40 p.s.i. are required to move the mercury in a reasonable period of time. The mercury flowing into the closed reservoir compresses the air in it, thus providing a means for controlling the volume of mercury moved, by use of a pressure-operated switch connected to this air volume. The air pressure to move the mercury is supplied directly by a small, electrically driven compressor mounted in the equipment. For an average treatment time of 10 minutes, the opening time of approximately 6 seconds is less than 1% of the treatment time. If the time clock which controls the shutter mechanism is connected so that it starts timing at the beginning of the opening cycle, and stops timing at the beginning of the closing cycle, errors in the dosage based on a treatment time so measured will be much less than 1%. Observations were made fluoroscopically with a 20 curie Ir^{192} source in place of the Co^{60} source (at the Radiology Laboratory, National Research Council) to check the movement of the mercury and the action of electrical contacts in the mercury which provide pilot light indications to the operator of the "on" and "off" positions of the shutter.

Many safety provisions are incorporated in the shutter mechanism. All electrical components are chosen to fail "safe", i.e. failure turns the unit off. If the normally open solenoid valve, which bleeds the compressed air from the port to turn the unit off, should fail to perform this function, a push-operated quick release valve is so mounted on the head that it may be opened manually by a broom handle or similar rod at some distance. This valve has a large orifice which turns the unit off in about 1 second. The only other possible mode of failure of the turn-off mechanism is complete loss of the mercury from its container. The use of stainless steel for mercury-containing parts, and high safety factors in calculating wall thicknesses for the pressures used, make this type of failure very improbable. In the event the mercury is lost, however, the source may be quickly and safely removed, since the field outside the beam allows work to be carried on for the required length of time without exposures to personnel beyond permissible limits (300 mr. for the operation).

A simple control panel, which may be situated in a remote location, carries the time switch and pilot lights. A key operated switch, controls use of the time switch, and a manual switch provides against failure of the time switch and other components in the control panel. A voltage failure relay prevents the shutter from opening automatically after voltage failure during a treatment.

This shutter mechanism and its controls perform satisfactorily, and appear to be a sound method of controlling the beam.

Beam Definition

The equipment is designed for treatment distances of from 50 cm. to 100 cm. Fixed cones are necessary from 50 cm. to 70 cm., while from 70 cm. to 100 cm. an adjustable aperture has been designed, providing square or rectangular apertures from 3 cm. x 3 cm. to 18 cm. x 18 cm. In all these cases, a minimum clearance of 14 cm. between the defining aperture and the patient is provided, while this clearance never exceeds 22 cm.

It is necessary to make a compromise between source diameter, clearance from aperture to patient, and the sharpness of the beam. The source diameter is determined by available pile fluxes and irradiation times. In order to check irradiation schemes and aperture design problems, three trial sources,

having physical dimensions similar to the final source, were irradiated to activities from 50 to 100 curies, and experiments with various collimating systems were performed for us by the Radiology Laboratory of the National Research Council, Ottawa. (Dixon and Fish, 1950). The penumbra is given by the simple geometrical formula:

$$x = D\left(\frac{a}{b} - 1\right)$$

where x = approximate penumbra width,

D = diameter of source,

a = treatment distance,

b = distance from source to most distant defining edge of aperture.

It is clear from the formula that, for sources of 2.5 cm. to 3.5 cm. diameter, which are practical sizes for irradiations in fluxes from 10^{13} to 4 x 10^{13} neutrons/cm^2/sec., the aperture edge which is most remote from the source must be as close to the skin as may be permitted. Consideration of electron emission from the aperture material and the resultant high skin dosage indicates that a minimum clearance of 10 - 20 cm. is desirable.

This led to the design of the adjustable removable diaphragm shown in Fig. 3. Here the distance from the source to the aperture may be varied as the treatment distance is varied, keeping a constant distance between the aperture and the skin. In order to make this possible in the space available, and as well to improve the definition of the beam, a single-plane adjustable defining system was evolved consisting of a combination of a steel channel and lead blocks, continuously adjustable to form square and rectangular apertures. The opposing faces of the channels and blocks may be advanced towards each other or withdrawn from each other by movement of a controlling cam, while the other two slides are constrained to follow, thus keeping the perimeter of the aperture intact. The thickness of defining material is 3" of lead or equivalent. The diaphragm may be rotated through 360° about the axis of the beam.

A fixed primary aperture limits the maximum size of the cone of radiation controlled by the adjustable aperture, and as well provides a basis for the addition of fixed cones should the adjustable aperture be removed. Treatment distances of a minimum of 50 cm. may be obtained in this way, or if fixed cones are preferred, they may be used for any other treatment distance greater than this without recourse to the detachable adjustable aperture. In clinical use, however, the adjustable aperture is very convenient since fixed cones tend to be bulky and heavy to handle.

Positioning

Two types of front-pointer have been designed for use with the equipment. Type **A** is a mechanical pointer which shows the axis of the beam and the treatment distance but must be swung aside during treatment. Type B is a thin transparent plastic cone fitting on the end of the housing of the adjustable aperture. The point of the cone establishes the treatment distance and the axis of the beam. Provision is made for attaching a back pointer, and one has been built for use with the equipment.

To assist in the orientation of the field on the patient, a light beam is arranged to approximately duplicate the radiation beam through the aperture. The method which has proved satisfactory is shown in Fig. 3.

The axis of the beam may be rotated about one horizontal axis through an angle of 105°, from 10° above horizontal to 5° past vertical, in 70 seconds by means of a motor driven worm gear mounted on the shaft which supports the head. This means that the linear speed of the backpointer when using 100 cm. treatment distance is approximately 1.5 cm. per second. This rate of movement is slow enough to enable accurate adjustments to be made without difficulty.

The horizontal arm supporting the head may be raised or lowered so as to position the source at 28 inches to 81 inches above the floor. This is done by means of a motor arranged to drive suitable mechanisms. Since the total weight of the head and its supporting arm is over 4000 pounds, the mechanism needs to be quite sturdy. The supporting arm moves freely on tracks provided in the vertical structure, and hangs on a bronze nut which engages a steel screw 2" in diameter. The screw moves the head at 1.25 cm. per second. The lead angle on the screw is such that the mechanism is self-locking. This method of raising and lowering the treatment head was chosen because it is very simple and can be designed so that it is very safe.

Rotation and vertical movement of the head is controlled by a small portable push-button station which is connected by a flexible cable to the vertical pedestal.

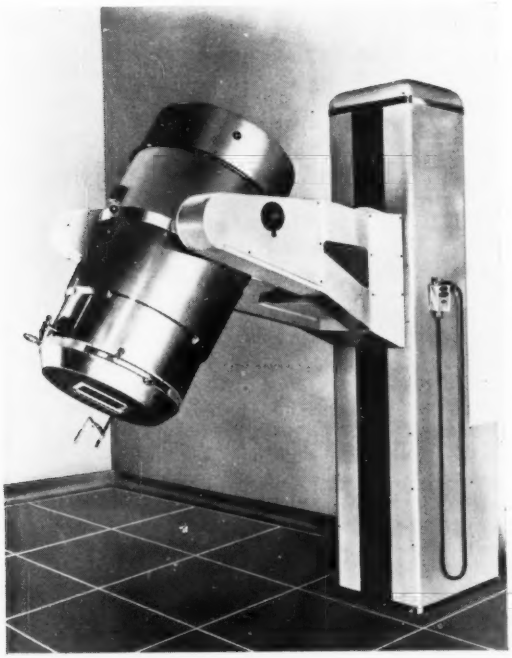

Figure 4

Structural Support

Considerable thought was given to the best style of structure to support the treatment head. Faced with the problem of designing equipment that could be installed with a minimum of alteration in a wide variety of treatment rooms, it was decided to employ a "gallows" type mount. A horizontal distance of 42" from the source to the pedestal, more than half the length of a treatment table, together with a pedestal only 19" in width, allows excellent manoeuverability of the treatment table. Suitably designed feet attached to the base of the pedestal make the equipment self-supporting and no structural alterations are required for installation. A simple and inexpensive false floor to cover the feet may be built in existing rooms to a height of $6\frac{1}{2}$ inches above the existing floor, flush with the top of the feet. In a new building, it is simpler to provide a recess in the floor of the correct depth and size for the feet, so that after installation the floor may be continued directly over the feet. The room must have a ceiling height of only 9 feet in order to install the unit, while a floor space of 16 feet x 12 feet is quite adequate for manoeuvering the treatment table when using up to 100 cm. treatment distances.

Conclusion

A simple, compact, flexible and relatively inexpensive equipment for supervoltage therapy may be built, using Co^{60} sources delivering up to 60 r/min. at 1 meter.

ACKNOWLEDGMENTS

We sincerely regret that time does not permit personal mention of all those who have assisted in this design, including the many physicists, radiologists and equipment suppliers with whom various aspects of the problem have been discussed. The wholehearted co-operation and assistance of the National Research Council of Canada, through its Atomic Energy Project at Chalk River, Ontario and, in particular, through its Radiology Laboratory in Ottawa, has been of very great value, and is deeply appreciated.

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THE BETATRON IN CANCER THERAPY*

Part II

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Saskatchewan, Canada

Carcinoma of the Cervix

Treatment was completed in ten patients, seven Stage 3 and 4, and three carcinoma of the cervical stump. Seven of these patients are alive (average seven months) and three are dead (average seven months).

Of the seven patients, who are alive, five are apparently well; one has continuing disease, and one is living following radical surgery for a recurrence.

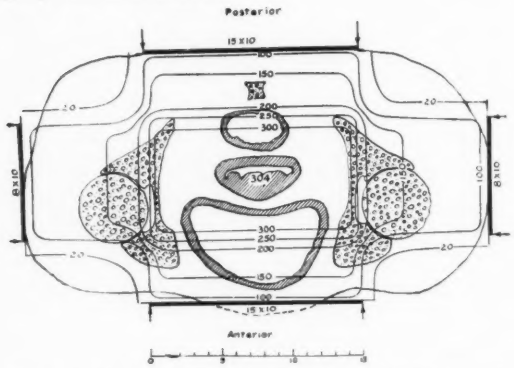

Fig. 2. Distribution of dose in pelvis for advanced carcinoma of cervix.

In all patients, large fields were used in an effort to irradiate the true pelvis to a homogeneous level. Usually anterior and posterior rectangular fields of 15 x 10 cms. and lateral fields of 10 x 8 cms. were used. Each pair was treated on alternate days. We would have preferred treating each patient daily, but the added complications of more frequent positioning of the patients, and, in view of the very low skin dose, the lack of skin effect, did not seem to warrant this method.

Four of the five patients who are apparently well received a tumor dose of 5830r - 6000r in seventeen to twenty-eight days, the number of treatment days being fourteen in each case. The long over-all time of twenty-eight days in one patient was due to a break-down of the machine. The other patient received a tumor dose of 7500r in thirty-three days (twenty-three treatment days).

In the five patients who are living with recurrence, or dead, the growth completely resolved in four, only to recur later in three. The fourth patient died with the disease apparently resolved. There was no post mortem examination, the death certificate reading "myocarditis". The fifth patient is alive with disease which showed little response.

Carcinoma of the Bladder

Nine patients have been treated. All were advanced and considered unsuitable for cystectomy or surgery of any sort.

Seven of these patients are dead (average seven months) and two patients are well (at twelve and seventeen months). These two patients each received a tumor dose of 6000r in eighteen or nineteen days (fourteen treatment days).

One of these patients who is dead was suffering from an advanced carcinoma of the bladder with multiple secondary deposits on the skin of the abdominal wall. A single large circular field, 15 cms. in diameter, was used, with wax in front of the skin so that a skin dose of 3500r in twenty days (fifteen treatment days) was given. A brisk erythema was produced.

Usually four fields were used, anterior and posterior parallel opposing pair, and a lateral opposing pair. The anterior and posterior fields were either 15 x 10 cms., or 10 x 10 cms., and the lateral fields 10 x 10 or 10 x 8 cms. The tumor dose in all cases varied from 3500r to 6000r in seventeen to twenty-five days, the usual number of treatments being fourteen. The maximum skin dose did not exceed 2100r, except in the patient just mentioned, who received 3500r. With this exception, none of these patients developed an erythema. Three patients developed diarrhoea towards the end of treatment, and in four, frequency of micturition became troublesome.

Carcinoma of the Lung

Ten patients of inoperable carcinoma of the lung have been treated, of whom seven are dead (average five months). Of the three that are alive, the tumour has apparently resolved in two (average six months) and the third, after a symptom-free period of four months, has now recurred.

Part I of this paper appeared in the December 1951 issue of the JCAR.

Five of the seven dead patients had marked relief of symptoms for periods of three to seven months. One patient gained seventeen pounds in two months following treatment, but died from secondary deposits.

The tumor dose in seven patients was 5500r to 6500r in an over-all time of eighteen to twenty-nine days. The three remaining patients had a tumor dose of 7500r in thirty-one to thirty-three days (twenty-five treatments). One patient who had a tumor dose of 7500r in thirty-one days is symptom free, as is another patient who had a tumor dose of 6000r in a period of nineteen days.

Usually two parallel opposing fields, one anterior and one posterior, were used, the size of the fields being between 15 x 10 and 15 cm. circle. In this way the tissue between was raised to a very homogeneous dose, except from the surface to three centimetres deep, both front and back, where the dose falls rapidly.

The maximum skin dose varied from 3200r - 4100r in seventeen to twenty-nine days and from 2350r - 4300r in thirty-one to thirty-three days.

The only erythema noted was in two patients who received 3600r to the skin in twenty and eighteen days respectively.

Four patients suffered from a temporary dysphagia towards the end of treatment and two complained of increased cough.

Carcinoma of the Rectum

Eight patients have been treated, of whom seven are dead (average ten months following treatment). One is alive with residual disease at sixteen months, and without symptoms.

The tumor dose varied from 3000r to 6000r in seventeen to nineteen days and the arrangement and size of the fields was similar to that described for carcinoma of the cervix.

The maximum skin dose varied from 1270r to 2560r. Two patients only developed an erythema — one who had 2200r to the skin in seventeen days and one who had 2000r in nineteen days.

Three patients developed urinary frequency and mild cystisis, and five diarrhoea either from colostomy or rectum. One of these patients developed intestinal obstruction after ten treatments and died. At post mortem, adhesions and ileitis were found. The tumor was mostly necrotic.

In view of the lack of response in this kind of tumor, no patients of this type have been accepted for some time.

Brain Tumor

Six patients have completed treatment. Of these, one patient (a glioblastoma) is dead and the remaining patients are symptom-free (average duration ten months). The patient who is dead was started on treatment in a comatose and almost moribund state. He rapidly recovered and remained apparently well for five months. He suddenly relapsed and died six months after this treatment. At post mortem the tumor was found to have recurred in the occipitoparietal area, which was posterior to the region treated.

The symptom-free patients are as follows:- One craniopharyngioma (fifteen months), two astrocytomas (one eleven months and one eight months) and two glioblastomata multiforme (one eleven months and one seven months). The patient with a craniopharyngioma was treated with beam direction, using a plaster cast. Four 6 cm. diameter fields were used, the tumor dose being 5500r, with a maximum skin dose of 2440r in nineteen days (fifteen treatments, each field daily).

All the other patients were treated with large single fields (10 x 8 cms. to 15 x 10 cms.), the tumor dose in all being 5500r, with a maximum entrance skin dose of 2200r and a maximum exit skin dose of 3740r in nineteen to twenty-three days (fifteen treatments). One patient was treated over thirty-one days, owing to a mechanical breakdown.

The only local reaction noted was epilation. Two patients has increase in headache during the first week of treatment. There were no constitutional reactions.

Carcinoma of the Oesophagus

Four patients have been treated, two of whom are alive, and two dead. All have had marked subjective and objective improvement.

One patient, who had a large carcinoma of the upper oesophagus, died suddenly three months later from a mediastinal abscess. At post mortem no residual carcinoma was found. A perforation of the oesophagus through the growth could be seen in his films before treatment. This patient had a tumor dose of 5500r in twenty-one days (fifteen treatments) using a plaster cast and three beam directed fields, each 15 x 6 cms. The other patient who is dead was well four months after treatment. He died seven months after treatment. There was no post mortem examination.

The two patients who are well at seven and four months received a tumor dose of 6500r in seventeen and eighteen days respectively. Both were treated with four fields, each 15 x 6, using a plaster cast and beam direction.

The maximum skin dose varied from 2870r to 1845r. Only one case developed an erythema — that which received 2870r in twenty-one days. There were no constitutional reactions.

Miscellaneous

In this group there are eleven patients. Five are dead and six alive. They all had advanced cancer for whom conventional therapy would have been of little or no value or some were already recurrent following treatment. Owing to the nature of their malignancy a large volume of tissue had to be irradiated in all except in two patients, viz: carcinoma of antrum and carcinoma of larynx, resulting in severe local tissue reactions.

The following are the diagnoses of the dead patients and the time of death after treatment.

1. Secondaries in the lung from carcinoma of breast — nine months. In this case the large secondary resolved.
2. Secondaries in the lung from hypernephroma — seven months.
3. Carcinoma of the vagina Stage IV — twelve months.
4. Secondaries in pelvis from carcinoma of stomach — ten months.
5. Secondaries in lung from cancer of the colon — seven months.

In all these patients some palliation was obtained as indicated by a period of relief from pain and/or a temporary disappearance of the tumor.

The six living patients with brief explanatory notes are as follows:

1. Carcinoma of the ovary—alive fourteen months but with residual disease and now distant metastases.
2. Carcinoma of the larynx — total laryngectomy attempted but failed. A tracheotomy was performed. Betatron irradiation causes a disappearance of the tumor which recurred locally several months later. A laryngo fissure was then possible and the growth was removed. Patient is alive without evidence of recurrence — twelve months.
3. Carcinoma of maxillary antrum — alive at nine months but with residual tumor after betatron irradiation and maxillectomy.
4. Post cricoid carcinoma — patient had received conventional x-radiation prior to betatron therapy. Tumor dose from the betatron irradiation was, therefore, small (4600r in three weeks). Patient is alive at seven months but with residual tumor.
5. Recurrent carcinoma of corpus uteri — alive and well without evidence of recurrence at four months.
6. Retrosternal carcinoma of thyroid — alive without evidence of recurrence at ten months. This patient had betatron irradiation to the mediastinum. Following the treatment he developed a grossly enlarged heart with congestive failure which subsequently cleared.

Discussion

It would seem that a 22 MeV betatron is a practicable machine for therapy, and perhaps a useful addition to radiotherapeutic armamentarium. It has a limited field of usefulness in the treatment of deep-seated lesions. It does not appear to have any obvious specific biological advantage over conventional x-rays, but does present certain physical attributes which can be used to advantage. Constitutional effects, due to low integral doses, are minimal. By using a suitable compensating filter, flat isodose curves are obtained which permit of simple lay-outs. Lack of variation of depth dose with field size also makes for simplicity. The low skin dose compared with a very high depth dose is obviously of great value. Skin reactions have been negligible, although high tumor doses have been obtained. No hazards peculiar to 22 MeV. x-rays have been observed. The machine which has been used is stationary, but new instruments with a range of movement are now being constructed, and should provide a distinct advantage in therapy. The immediate results, in advanced cases of cancer of the cervix and bladder, were quite hopeful in that there was, in most cases, a disappearance of the tumor. Although it is easy to deliver a very homogeneous dose to the entire pelvis, the tumor recurred locally in many of these. This indicates that a tumor disappearance, rather than a tumor lethal, dose was given. In our experience it has been impossible to achieve a tumor lethal dose in the majority of cases in three weeks as the reaction to the bladder and bowel has been the limiting factor. The limiting factor in the treatment of the cervix is the effect on the bowel and bladder, as with radium, but a very homogeneous irradiation to the pelvis is possible. In our experiments a tumor dose of 6000r to the whole pelvis delivered in three weeks was considered the maximum possible. Undoubtedly, with smaller volumes, the tissue tolerance must be much higher. It should be emphasized that all patients treated have been in very advanced stages of malignant disease. This has usually necessitated the use of much larger fields than one would have liked to use. Considerable palliation was

achieved in advanced tumors of the lung and brain. Cancer of the rectum has shown a very disappointing response.

This entire paper refers to experience with x-rays. No patients have been treated with the electron beam. It would seem that suitable cases for high energy electron therapy would be rare. There are also severe practical difficulties in the arrangement of a homogeneous tumor dose.

Summary:

The immediate effects of the irradiation of fifty-eight patients using a 22 MeV betatron are presented.

Only far advanced malignant cases have been treated. Some favorable immediate results were obtained in carcinoma of the cervix, urinary bladder and brain tumor. There was little effect in advanced cases of carcinoma of the rectum. The betatron is considered to be a practicable deep therapy machine. No unexpected deleterious effects have been observed.

Acknowledgments:

The authors wish to acknowledge the great amount of preliminary physical investigation mainly performed by Dr. H. E. Johns, Professor of Physics, University of Saskatchewan, and physicist to the Saskatchewan Cancer Commission. Mr. R. Mauchell, technician in charge of the betatron, has provided invaluable assistance. Professors Harrington, Haslam and Katz, all of the Physics Department of the University of Saskatchewan, are thanked for their cooperation and helpful suggestions. The National Cancer Institute of Canada has provided financial assistance in this work.

Dr. A. C. Singleton has been elected Chancellor of the American College of Radiology at its annual meeting, February 8th, 1952, in Chicago.

BOOK REVIEW

Radiologic Physics, Second Edition, by Charles Weyl and S. Reid Warren, Jr., (Charles C. Thomas, Springfield Ill.) 1951. Canadian price, $12.50.

This second edition of Radiologic Physics (first published in 1941) presents changes in the form of increased space alloted to electronics and the addition of recent material such as the use of radioisotopes. The foreword by Dr. E. P. Pendergrass indicates that the book is intended primarily for physicians who are studying radiology as a specialty.

The authors introduce the electrical basis of radiology in an elementary manner, starting with the fundamentals of electricity and using numerical examples though avoiding mathematics as far as possible, the assumption being, apparently, that the reader may never even have seen a piece of insulated wire before. However, electronics power, distributing systems and x-ray generators including the cyclotron and betatron are soon introduced. Then radiation itself is treated, beginning with an introduction to nuclear physics and the interaction of x-rays with matter and going on to the practical applications of physics to tracer work and therapeutic and diagnostic radiology. The latter topic is quite well covered.

Though the book is presented from an engineering point of view, in that practical aspects of design and operation of apparatus are emphasized, the physicist will find much of it rather elementary and would like to see some of the topics carried further. The physician entering radiology, on the other hand, may be disturbed by the range of material covered, including such topics as MKS units, relativistic motion of electrons and high vacuum technique. In the reviewer's opinion neither the very elementary approach nor the extraneous topics mentioned above are needed in a book intended for radiology students.

In summary, it may be said that though the material is all pertinent to radiology and is strictly accurate, this book is not so suitable as a textbook for the training of radiologists as for collateral reading. The physicist in general, will not find the material sufficiently advanced, as might be expected in a book which avoids higher mathematics.

L. G. Stephens-Newsham.

BOOKS RECEIVED

Books received are acknowledged in this department, and such acknowledgment must be regarded as a sufficient return for the courtesy of the sender. Selections will be made for review in the interests of our readers and as space permits.

The Skull and Brain Roentgenologically considered, by C. Wadsworth Schwartz and Lois Cowan Collins. Charles C. Thomas, Springfield, Illinois.

Roentgen Examinations in Acute Abdominal Disease, by J. Frimann-Dahl. Charles C. Thomas, Springfield, Illinois.

Roentgen-Diagnostics, Volume I, by H. R. Schinz, W. E. Baensch, E. Friedl, E. Uehlinger. First American Edition (based on the Fifth German Edition) English translation arranged and edited by James T. Case. Charles C. Thomas, Springfield, Illinois.

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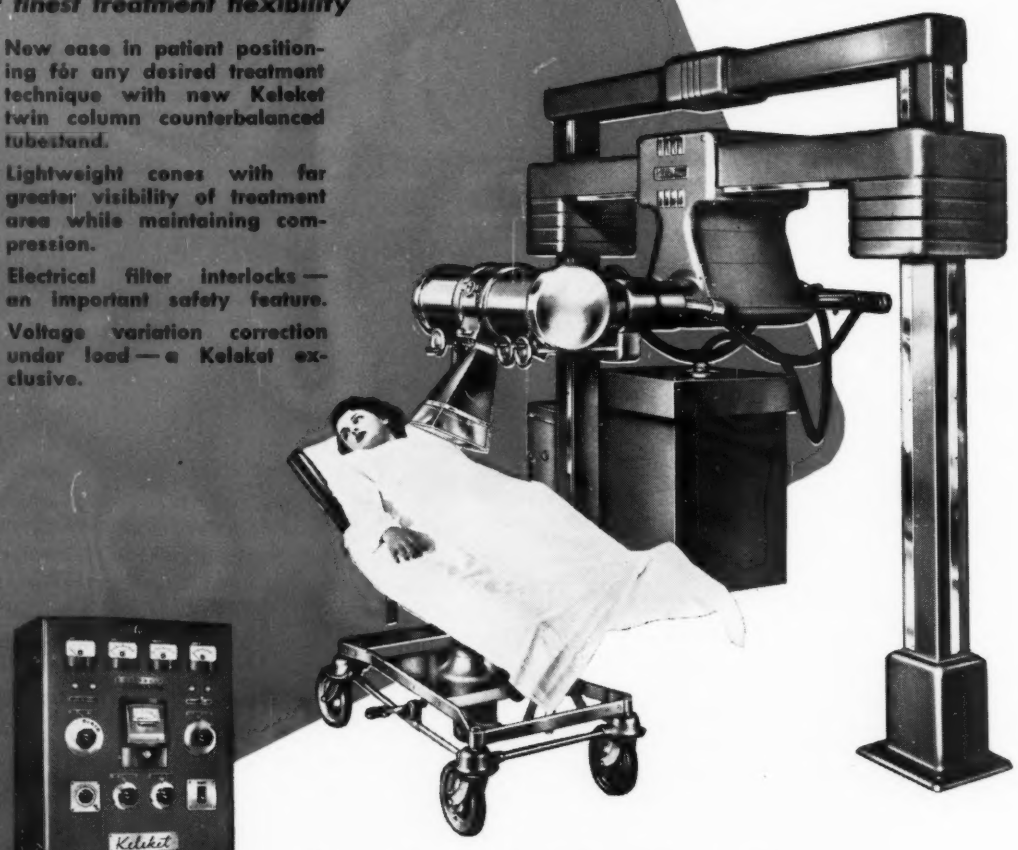

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SPECIAL GENERAL MEETING — BANFF, JUNE 1952

In conjunction with the Annual Convention of the Canadian Medical Association at Banff in June of this year, the Canadian Association of Radiologists will hold its yearly Special General Meeting.

DELEGATES — 7th INTERNATIONAL CONGRESS

The following members were elected as the Canadian Delegation from this Association to the 7th International Congress of Radiology to be held in Copenhagen in July 1953.

Chairman
Dr. Digby Wheeler, Winnipeg

Alternate Chairman
Dr. E. M. Crawford, Montreal

Delegates
Dr. Jean Bouchard, Montreal
Professor H. E. Johns, Saskatoon
Dr. H. Lapointe, Quebec
Dr. R. A. Macpherson, Winnipeg

Alternate Delegates
Dr. A. E. Broome, Kitchener
Dr. A. C. Singleton, Toronto
Dr. J. E. Perron, Quebec
Dr. E. A. Petrie, Saint John

4th INTER-AMERICAN CONGRESS OF RADIOLOGY
MEXICO - NOVEMBER 2nd - 8th, 1952

Any member expecting to attend the 4th Inter-American Congress and who would like to be appointed as official delegate of our association is requested to communicate with this office. It is understood, however, that no financial obligation will be incurred by the Canadian Association of Radiologists through any such appointment.

Honorary Secretary-Treasurer.

4th ARGENTINA CONGRESS OF RADIOLOGY

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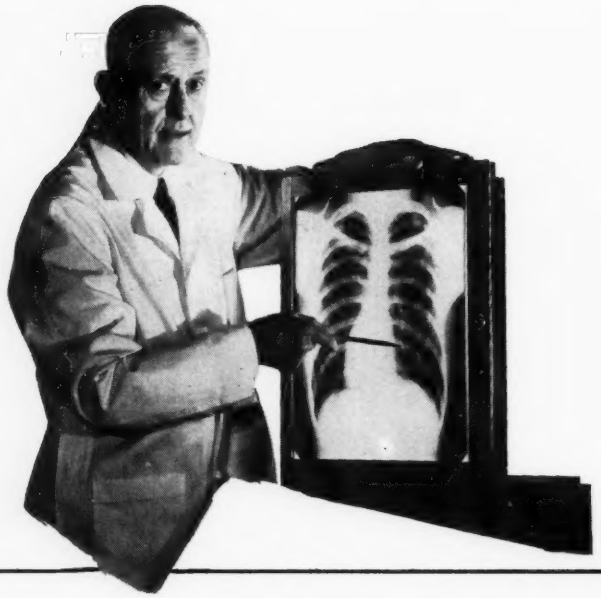

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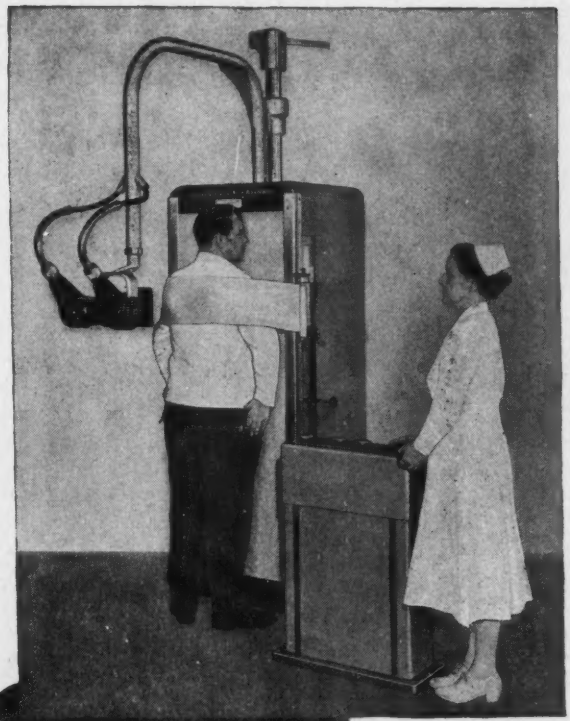

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